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GEOLOGIC AND GEOCHEMICAL STUDIES OF THE NEW ALBANY GROUP (DEVONIAN BLACK SHALE) IN ILLINOIS TO EVALUATE ITS CHARACTERISTICS AS A SOURCE OF HYDROCARBONS

Quarterly Progress Report for October 1—December 31, 1978

By
Robert E. Bergstrom
Neil F. Shimp

January 1, 1979

Work Performed Under Contract No. EY-76-C-05-5203

Illinois State Geological Survey
Urbana, Illinois

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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Robert E. Bergstrom and Neil F. Shimp
Principal Investigators

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Quarterly Progress Report - October 1-December 31, 1978
Report ORO-EY-76-C-05-5203-3

January 1, 1979

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GEOLOGICAL EVALUATION

Introduction

This project is a detailed analysis of the lithology, stratigraphy, and structure of the New Albany Group in Illinois to determine those characteristics of lithology, thickness, regional distribution, vertical and lateral variability, and deformation that are most relevant to the occurrence of hydrocarbons.

This study will result in the preparation of cross sections, facies maps, and geologic structure maps based on subsurface data available in the Illinois Survey files. Previous work in Illinois is being re-evaluated and updated. New data on the physical, chemical, and mineralogic characteristics of the New Albany will be derived from the studies of new cores in Illinois and will be incorporated into the stratigraphic and structural investigations of existing data.

Advise DOE on Drill Sites and Coring

Progress

The "grass roots" core in Hardin County, Illinois, near the center of the depositional basin of the New Albany Group, began on 29 November 1978. A complete report of that core is given below. Contact has continued with basin operators on other possible coring sites in Illinois, but no firm commitments have been obtained.

Problems

As anticipated, the Hardin County core was heavily fractured. The fracturing and the unanticipated hardness of the shale caused many problems in coring as outlined below. The usefulness of the core for strength and directional properties and gas content is doubtful. However, recovered segments are good for stratigraphic and petrographic investigations. Another core in the Illinois Basin is desirable, preferably in the Hamilton County area, in order to complete our resource evaluation.

Summary of coring operations

Core Report for EGSP ILL #4 (ISGS core 11 IL)
Rector and Stone Drlg.
Missouri Portland Cement #1
NE¼ NE¼ NE¼ Sec. 36, T. 11 S., R. 7 E.
Hardin County, Illinois
Ground Elevation estimated at 560 ft. (171 m) above mean sea level from topographic map.

Drilling began at 1625 hrs. on 29 November 1978. A 12½" hole was drilled to 33 ft. and 8 5/8" surface casing was set. 7 7/8" hole was drilled to 35 ft. Coring began at 2015 hrs. using a 7 7/8" coarse diamond bit without orienting equipment.

Core 1: start 35' @ 2015, 11/29/78
end 40' @ 2156, 11/29/78
core barrel jammed

Core 2: start 40' @ 2245, 11/29/78
end 44' @ 2334, 11/29/78
core barrel jammed

Core 3: start 44' @ 0014, 11/30/78
end 49' @ 0140, 11/30/78
core barrel jammed

Core 4: start 49' @ 0259, 11/30/78
end 52' @ 0419, 11/30/78
core barrel jammed

Recovery from 35 to 52 ft. was extremely poor. Only small pieces of broken core and rubble were recovered, representing approximately 10 percent of the total interval cored. The formation through this interval is highly fractured and mineralized, and the core apparently broke along natural high angle fractures as it entered the inner core barrel. The Christensen representative suggested drilling to 68 ft. so that the upper core barrel stabilizers could ride within the 7 7/8" hole and below the surface casing. This would reduce wobble at the core bit and possibly would reduce core breakage.

7 7/8" hole was drilled to 68.5 ft. Problems were encountered lowering the core barrel into the hole and the interval from 35 to 68 ft. required reaming and washing with the coring bit. Coring resumed at 0815 hrs.

Core 5: start 68' @ 0814, 11/30/78
end 69.7' @ 0848, 11/30/78
pulled to check bit
rec. 0.7' whole core

Core 6: start 69.7' @ 0936, 11/30/78
end 74' ± 1014, 11/30/78
pulled to check bit and core catcher due to extremely slow coring rate
rec. 4.3' highly fractured and broken core

Problems were encountered pulling the core barrel out of the hole because the shale was apparently breaking along fractures and caving into the hole. Driller mixed mud and circulated for 20 minutes in an attempt to heal hole damage. Resumed coring at 1400 hrs.

Core 7: start 74' @ 1402, 11/30/78
end 78' @ 1743, 11/30/78
pulled due to slow drilling rate (35-59 min/ft.)
rec. 3.8' badly broken core

Core 8: start 78' @ 1821, 11/30/78
end 79.3' @ 1929, 11/30/78
pulled due to very slow drilling rate (3 inches in last 30 min.)
rec. 1' badly broken core rubble
changed to finer diamond bit, replaced core shoe, replaced core barrel bearing

Core 9: start 79' @ 2202, 11/30/78
end 84' @ 0434, 12/1/78
pulled core due to extremely slow drilling rate during last foot (120 min.).
rec. 4' partly broken core with a few long pieces

Core 10: start 84' @ 0611, 12/1/78
end 85.5' @ 0833, 12/1/78
pulled core due to extremely slow drilling rate (94 min/ft.)
rec. 2' whole core (one piece 1.5' long)
changed back to coarse diamond bit

Core 11: start 85.5' @ 0848, 12/1/78
end 88.5' @ 1323, 12/1/78
pulled core to change bits
rec. 1.3' whole core

Several very hard zones were encountered while drilling cores 7-11. It was necessary to drill out the 1.5 ft. of lost core from the last run and the rock bit was severely dulled while cleaning out the bottom of the hole—further demonstrating the extremely hard nature of the shale at this site. We decided to change to a 6 3/4" O.D. coring bit to reduce the amount of rock drilled and hopefully increase the drilling rate. Coring resumed at 1515 hrs.

Core 12: start 88.5' @ 1518, 12/1/78
end 92' @ 1808, 12/1/78
pulled core due to slow drilling rate through last foot (73 min.).
rec. 2.5' whole core and 0.5' rubble

Core 13: start 92' @ 1838, 12/1/78
end 96' @ 2145, 12/1/78
pulled core due to slow drilling rate through last foot (73 min.)
rec. 3' whole core and 1' rubble

Core 14: start 96' @ 2235, 12/1/78
end 99.5 @ 0127, 12/2/78
pulled due to slow drilling through last 0.5 ft. (45 min.)
rec. 3/5' core, broken into 0.4-0.8' long pieces.

Core 15: start 99.5' @ 0219, 12/2/78
end 103' @ 0541, 12/2/78
pulled due to slow drilling through last foot (70 min.)
rec. 3.5' badly broken and fractured core

Core 16: start 103' @ 0631, 12/2/78
end 119' @ 1546, 12/2/78
pulled to change upper core barrel stabilizer to 6 3/4" size
rec. 15.8' core (12' whole core and 4' rubble)
Avg. drilling rate = 34 min./ft.

Core recovery was high enough in quality to allow orienting. The field team decided to mount the MONEL collar and orienting camera and attempt to cut an oriented core. First oriented core started at 1735 hrs.

Core 17: start 119' @ 1735, 12/2/78
end 136' @ 0900, 12/3/78
rec. 15' core; mostly in 1-1.5' pieces, some badly broken zones (probably lost 2' at about 132')
avg. drilling rate = 52 min/ft.

Core 18: start 136' @ 1055, 12/3/78
end 166' @ 1540, 12/4/78
rec. 28.5' core; broken at bottom. Probably lost 1.5' near base
avg. drilling rate = 55 min/ft.

Core 19: start 166' @ 1727, 12/4/78
end 191.5' @ 0707, 12/5/78
rec. 21' mostly whole core from 166' - 173'. Estimated 2' lost between 173.5 and 175.5 (drillers lost circulation through this zone). Core below 175.5' is highly broken and fractured; mostly along coring induced disc fractures. Estimated 3.5' lost at bottom of core (very rapid drilling through this interval).
avg. coring rate = 23 min/ft.

Core 20: start 191.5' @ 1116, 12/5/78
end 225' @ 0703, 12/6/78
rec. 32.5'. First 2.5' of core were pulled from barrel during a bit check @ 1300 hrs. 12/5/78
most of core to 223' in good condition. Bottom of core highly broken and pulverized.
average coring rate = 31 min/ft.

Core 21: start 225' @ 1110, 12/6/78
end 245' @ 2209, 12/6/78
core barrel jammed
rec. 19.5' mostly broken along coring induced disc fractures every 0.2-0.5'. 0.5' core lost at bottom
average coring rate = 29 min/ft

Core 22: start 245' @ 0054, 12/7/78
end 269' @ 1741, 12/7/78
core barrel jammed
rec. 16', mostly broken along coring induced disc fractures every 0.2 - 0.5', bottom of core at 261'; estimated 8' lost in hole
average coring rate = 39 min/ft.

The lower end of the orienting shoe had been ground off where it joins the main barrel of the core catcher, apparently by a piece of shale which must have wedged between the inner and outer core barrels. All five core catcher slips and all orienting knives were lost in the hole. The drilling crew and Christensen representatives advised the ISGS field team that most of this material was tungsten and could not be fished out of the hole magnetically, and was too small to be picked up by a junk basket. They believed the metal could probably be ground up with a rock bit and then washed out of the hole—but it would be impossible to determine if all the pieces had been removed and any one of them would rapidly destroy a diamond coring bit. The site geologist called off coring operations at the time (1930 hrs., 12/7/78). DOE was contacted and orders were received to drill out to the base of the shale prior to logging the hole.

Drilling commenced at 2347 hrs. (12/7/78) and continued to 0639 hrs. (12/8/78). Base of the New Albany Shale was encountered at approximately 331 ft. as determined by drilling rate and on-site inspection of cuttings. Drilling continued an additional 39 ft. to allow the longest logging tool to be accommodated below the contact. Driller's total depth was 370 ft.

Mud was mixed and circulated through the hole until 0840 hrs., 12/8/78. Logging commenced at 1200 hrs. The dual-induction laterolog, spontaneous potential, compensated neutron porosity, bulk density, and gamma ray logs were successfully run that afternoon. At 1712 hrs. the sonic tool was lost in the hole while raising it to ground level. The upper centralizer apparently caught on the rotary table, which was not visible to the winch operator on the logging truck. The tool broke at the weak point in the logging head. It was successfully fished out of the hole on the first attempt at 0500 hrs., 12/9/78. Logging resumed at 1000 hrs., after repairing the sonic logging tool. The microlaterolog was started at 1240 hrs. The field team left the site before logging was completed, with only the fracture identification log remaining to be run.

Structure Map on Base of New Albany

The revision of the previously published geologic structure map on the base of the Devonian black shale (top of the Hunton Limestone Megagroup) has been completed. The map was revised on the basis of the recently updated Devonian well file previously completed for the DOE project. The updating greatly increases the accuracy of the previous map in certain areas where questionable data had been used. The revised map will appear in future Survey publications.

Stratigraphic Cross Sections

This project is essentially complete. No new cross sections have been produced during the past quarter. Four simplified sections are being prepared from existing sections for illustration in the forthcoming Survey publication dealing with the stratigraphy and lithology of the New Albany Group in Illinois.

Isopach Maps

Most of the formation thickness maps have been submitted to drafting for final preparations as illustrations in the forthcoming Illinois Survey publication on the New Albany. Further revisions have been made in the maps of the Grassy Creek and Sweetland Creek Shales as new data and new insights have come to shed light on areas of poor control. Therefore this project is essentially complete, except for some minor revisions that may come from new data or from discussions with our counterparts in Indiana and Kentucky.

The coordination meeting tentatively planned for early December was postponed until 19 January in Bloomington, Indiana. At that time we hope that remaining border problems with the position of isopach lines can be resolved between Indiana, Kentucky, and Illinois.

Sample Studies

During the past quarter, about 35 well sample sets were studied. Samples were taken from each 100 foot interval for vitrinite reflectance, clay mineralogy, and chemical analyses. Lithologic descriptions were compared to geophysical log characteristics and stratigraphic contacts were adjusted to log depths.

In addition, to compare the New Albany Shale with other formations in the stratigraphic column, five deep wells were sampled for vitrinite reflectance data and chemical analyses.

This project has produced a great deal of valuable information that has enabled us to better pick lithologic boundaries on geophysical logs and to better evaluate the lithology represented by the geophysical log. Samples for vitrinite reflectance have given a three dimensional control to that aspect of the mineralogic evaluation that would otherwise have been impossible if we relied on cores only.

All necessary samples have been taken and this aspect of our study has been successfully completed.

Linear Features of Illinois

A great number of linear features are visible on LANDSAT images, Skylab photographs, and aerial photographs of western Illinois. These linear features were investigated as part of the DOE study of geologic structure related to possible gas resource in the New Albany Group in Illinois. The result of the study was that these linear features were glacial in origin, formed by previously unrecognized drumlins, drumlinized and glacially fluted or grooved topography. As a result of these discoveries, we feel that careful evaluation needs to be made of linear features in glaciated areas before assuming that they are representative of some underlying bedrock structure.

A report on the glacial features of western Illinois is being prepared. Since these are glacial landforms, the publication will be addressed to their glacial origin and meaning in the overall picture of glaciation in that region of Illinois, but it will be emphasized that these features impart a linear texture to the topography that could be misinterpreted as bedrock structure by the unwary.

Publications

Reinbold, Mark L., 1978, Stratigraphic relationships of the New Albany Shale Group (Devonian-Mississippian) in Illinois: U.S. Department of Energy, Morgantown Energy Technology Center, Second Eastern Gas Shales Symposium Preprints, v.1, p. 443-454.

Reinbold has prepared an abstract to be submitted for the Ninth International Congress of Carboniferius Stratigraphy and Geology (IXICC) to be held in Urbana, Illinois, in May 1979. This abstract is intended for the planned symposium on the Mississippian type section and its correlation to Europe. The Hannibal Shale, and its lateral equivalents included in the Grassy Creek Shale are Mississippian in age. The abstract is given below.

FACIES RELATIONSHIPS, FORMATIONAL BOUNDARIES, AND TIME-ROCK STRATIGRAPHY IN THE UPPERMOST DEVONIAN AND LOWERMOST MISSISSIPPIAN STRATA (UPPER PART OF NEW ALBANY SHALE GROUP) IN ILLINOIS, U.S.A.

REINBOLD, Mark L., Illinois State Geological Survey, Urbana, IL 61801

The New Albany Shale Group and equivalent strata in the Illinois Basin can be classed into five main lithologies: black or brownish black shale, gray to greenish gray shale, calcareous or dolomitic shale, siltstone, and limestone. Black shale predominates near the center of the basin, whereas gray to greenish gray shale and siltstone dominate the basin margins. Detailed stratigraphic correlations based on geophysical logs, cores, and sample studies indicate that these lithologies intergrade laterally and vertically, with complex intertonguing relationships. Consequntly, in order to maintain the essential lithologic uniformity of defined formations, arbitrary vertical cutoffs are conveniently used to adjust formational boundaries stratigraphically upward or downward.

Vertical adjustment of formational boundaries to compensate for facies changes complicates biostratigraphic zonation and time-rock classification of formational units. The span of geologic time represented by a facies-defined formation in the subsurface near the center of the basin may be substantially different from the biostratigraphic range of the formation based on conodont studies of outcrops at the basin margins. For example, conodont work has shown that the dominantly greenish gray Hannibal Shale (Kinderhookian) in western Illinois is equivalent to dominantly black shale in the upper part of the Clegg Creek Member of the New Albany Shale in southeastern Indiana. Although subsurface biostratigraphic data are lacking, the upperpart of the black Grassy Creek Shale in the deep basin can be traced parallel to bedding planes into the Hannibal and upper Clegg Creek, and is therefore, by implication, Kinderhookian in age. However, biostratigraphic studies of the outcrops have confined the Grassy Creek to well within the Upper Devonian. Other similar problems in stratigraphic classification are apparent in the New Albany Shale study.

Work has progressed on a paper which summarizes the stratigraphy, lithology, structure, and depositional environment of the New Albany Shale in Illinois. Much of the initial rough draft of this manuscript has now been prepared. Publication as a ISGS Circular is expected in early 1979.

MINERALOGIC AND PETROGRAPHIC CHARACTERIZATION

Introduction

This project is directed at characterizing in detail the mineralogic and petrographic properties of the New Albany Shale in Illinois. This includes the quantitative and qualitative characterization, by optical and x-ray techniques, of the inorganic mineral constituents, the dispersed organic matter, and the fabric of the shale. The data generated will provide a fundamental basis for regional and local correlations of geologic data, for interpretation of the sedimentology, depositional environment, diagenetic history, and for evaluation of hydrocarbon potentials based on the degree of thermal maturation of organic matter in the New Albany Shale.

Lithologic and Radiographic Characterization

Progress

In this quarter, lithologic descriptions for samples from the 01KY (Christian Co., Kentucky) and the 01IL (Sangamon Co., Illinois) cores were revised and modified to conform with the FY 1978 reporting format. The data on these cores were originally reported in our FY 1977 Annual Report but since then substantial changes have been made in the method of tabulating data. Some descriptions also required modification due to more accurately characterized multiple-lithology samples. These revised descriptions are presented in Tables 1 and 2.

Seven samples obtained this quarter from a core in Fayette Co., Illinois (10IL) are being processed. A description of this core appeared in the October quarterly report.

The selection of supplementary drill cutting samples was completed this quarter. The locations of these samples are listed in Tables 3 and 4. Samples through NAS-477 will be analyzed for clay mineralogy, vitrinite reflectance, thin section petrography, and trace element geochemistry techniques to help determine geographic variations of these properties of the New Albany in Illinois. A few samples from Indiana and Kentucky are included in this group. Progress on these analyses is reported in the sections below. Samples NAS 478 through 521 were selected for studies of their organic maturity and they will be discussed in the section on vitrinite reflectance.

Microscopic Characterization

Progress

The scanning electron microscope (SEM) work is intended to provide some information on the general fabric and mineralogy of the shales. Shale samples have been prepared in a number of ways to examine different characteristics. Fracture surfaces, fracture surfaces etched with HCl and polished surfaces etched with HF have been examined. Samples have been coated with Au/Pd or Au. A number of problems have limited microscope usage and progress has been delayed. Despite these, a number of notable characteristics have been noted and are discussed below.

Fracture surfaces which cut across bedding planes show consistent linear trends at low magnification (100X) suggesting a systematic ordering of particles (see Plate 1A). At higher magnifications (500X), it becomes evident that these linear trends result from the orientation of the clay flakes. The relatively flat surfaces of illite flakes are oriented parallel or nearly parallel to the bedding plane as illustrated in Plate 1B. The linear fabric becomes less distinct when more rounded and subrounded clay, quartz, feldspar and other particles are present. The nature of the nearly flat, smooth surface of the illite flakes is illustrated in Plate 1C.

Commonly, pyrite framboids are observed. Smooth, spherical forms have also been observed as illustrated in Plate 1D. This form may be a diagenetically altered framboid. Note how the clay flakes partially envelope the pyrite sphere. Note also that some clay crystals occur in an indentation of the pyrite sphere. This identation may be organic in origin because reflected light studies have demonstrated that pyrite may grow and replace certain types of organic matter.

Dolomite rhombohedrons are common in some specimens. These crystals have been most successfully observed after the specimen has been polished and then etched with HF acid. Plate 1E shows clearly the form and the etch pattern common to these crystals. Note the close association of the quartz crystals on the upper surface of the rhomb.

Occasionally during the course of this work we have observed particles suspected of being organic matter, such as the one shown in Plate 1F. This particle displays a morphology reminiscent of humic matter and the anomalously low amount of x-rays obtained from it supports this interpretation. It is probably one of the fiberous particles of bitumin or a rare form of vitrinite. Further work is needed to verify the identity of the organic particles.

X-Ray Diffraction Mineralogy and Clay Orientation

Progress

Clay mineralogy of 61 supplementary drill cutting samples was completed this quarter. Data for these samples are presented in Tables 5-7. As noted in earlier reports, samples with anomalously low illite (<5) and high kaolinite contents may be contaminated by Pennsylvanian shale cavings.

Vitrinite Reflectance

Progress

In this quarter, 31 new samples have been analyzed for vitrinite reflectance. The data are presented in Tables 8-10. The data continue to support the trend of increasing reflectance to the south and east as reported in our September 1978 quarterly report. Corrected vitrinite data are reported in Table 11. Data collected from the remaining drill cutting samples including samples from Illinois, Indiana and Kentucky should give us a very clear picture of the trends and patterns of vitrinite reflectance. A preliminary isoreflectance map showing the maturity of the New Albany in Illinois was presented in October at the Annual Meeting of The Geological Society of America. Upon completion of the vitrinite reflectance analyses just mentioned, this map will be revised, up-dated, and copies will be included in our next report to DOE on this project.

A number of dark shales, hopefully vitrinite bearing, were hand picked from cuttings at various depths from three deep wells in Illinois. This work, proposed for FY1979, will permit us to evaluate the effect of the rate of increase of reflectance with depth (an index of the thermal gradient) as it relates to the maturity of the New Albany in Illinois.

Problems

In this quarter, a number of samples required re-examination because of anomolous vitrinite reflectance readings or unusually high standard deviations.

TABLE 1: REVISED LITHOLOGIC CHARACTERIZATION, CHRISTIAN COUNTY, ILLINOIS CORE SAMPLES

SAMPLE NUMBER	DEPTH* (FT)	FORMATION	LITHO-FACIES	%	BED TK.	GRAIN SIZE	MUNSELL COLOR	LAMINATIONS TYPE	LAMINATIONS TK.	LAMINATIONS SPACE	BIO-TURB.	SYNAERESIS EARLY	SYNAERESIS LATE	PYRITE NODULES SIZE	PYRITE NODULES AB.	PYRITE NODULES DIST
01KY01L1	2181.0	GRASSY CREEK SH	IVA	100	TKB	8	N1	E	VTNL	VTNL	0			10-10	1	BD
01KY01C1	2182.3	GRASSY CREEK SH	IVA	100	TKB	8	5YR2/1	E	VTNL	VTNL	0			1-30	10	BD
01KY02L1	2188.6	GRASSY CREEK SH	IVA	100	TKB	8	5YR2/1	E	VTNL	VTNL	0		15	1- 1	>25	RN
01KY02C1	2191.2	GRASSY CREEK SH	IVB	100	TKB	8	5YR2/1	E	VTNL	VTNL	0			1-30	>25	BD
01KY03L1	2216.7	GRASSY CREEK SH	IVB	100	TKB	8	5YR2/1	E	VTNL	VTNL	0		2	1-10	>25	BD
01KY03C1	2220.3	GRASSY CREEK SH	IVB	100	TKB	8	5YR2/1	E	VTNL	VTNL	0			1-20	>25	BD
01KY04C1	2230.2	GRASSY CREEK SH	IIB	50	VTNB	8	5YR2/1	MS			1	1		0- 0	0	
01KY04C1		GRASSY CREEK SH	IIB	50	VTNB	8	5Y4/1	MS			3	>25		4- 8	3	BU
01KY04L1	2231.0	GRASSY CREEK SH	IIIA	100	TKB	8	5YR2/1	DE	TNL	ML	0			2-10	20	BD
01KY05C1	2240.2	GRASSY CREEK SH	IVB	50	TNB	8	5YR2/1	E	VTNL	TNL	0			1- 5	>25	BD
01KY05C1		GRASSY CREEK SH	SS	50	TNB	3	5YR2/1	MS			0			1- 8	>25	RN
01KY05L1	2244.1	GRASSY CREEK SH	IVB	100	TKB	8	5YR2/1	E	VTNL	TNL	0			1- 3	>25	BD
01KY06C1	2250.0	SWEETLAND CR.SH	IIB	100	TKB	8	5Y4/1	MS			4	>25		2- 5	20	BU
01KY06L1	2255.4	SWEETLAND CR.SH	IIB	100	TKB	8	5Y4/1	MS			4	>25		2-10	20	BU
01KY07C1	2260.3	SWEETLAND CR.SH	IIIA	100	TKB	8	5YR2/1	E	VTNL	ML	0			3-20	20	BD
01KY07L1	2263.7	SWEETLAND CR.SH	IIIA	70	TNB	6	5YR2/1	W	ML	ML	0			10-12	2	BD
01KY07L1		SWEETLAND CR.SH	IIIA	30	TNB	8	N1	DE	TNL	ML	0	5		2- 5	5	RN
01KY08C1	2270.3	SWEETLAND CR.SH	IIIA	100	TKB	8	5YR4/1	EN	TNL	TKL	1	10		1- 4	15	BD
01KY08L1	2273.5	SWEETLAND CR.SH	IIB	100	TKB	8	N2	DE	VTNL	TKL	1	>25		1- 5	>25	RN
01KY09C1	2280.0	SWEETLAND CR.SH	IIIA	100	TKB	8	5YR2/1	DE	TKL	TKL	1	20		1- 4	15	RN
01KY10L1	2287.8	SWEETLAND CR.SH	IIIB	100	TKB	8	5YR2/1	DE	TNL	TNL	0	5		1- 3	15	BD
01KY10C1	2290.8	SWEETLAND CR.SH	IIIB	100	TKB	8	5Y2/1	E	VTNL	TNL	0	>25		1-20	>25	BD
01KY11L1	2292.9	SWEETLAND CR.SH	IIB	60	TNB	8	5YR2/1	MS			3	20		2- 4	20	BU
01KY11L1		SWEETLAND CR.SH	IIIB	40	TNB	8	5YR2/1	E	VTNL	TNL	0	15		1- 3	10	RN
01KY11C1	2299.8	SWEETLAND CR.SH	IIIA	100	TKB	8	5YR2/1	E	TNL	TNL	0			1- 4	25	BD
01KY12C1	2310.5	BLOCHER SH.	IVB	100	TKB	8	5YR2/1	E	VTNL	VTNL	0			1- 4	20	BD
01KY12L1	2311.1	BLOCHER SH.	IVB	100	TKB	8	5YR2/1	E	VTNL	VTNL	0			1-10	>25	BD
01KY13L1	2312.6	BLOCHER SH.	IVA	100	TKB	8	5YR2/1	E	VTNL	VTNL	0			1- 5	20	BD
01KY13C1	2318.8	BLOCHER SH.	IVA	100	TKB	8	N2	E	VTNL	VTNL	0			3-20	10	BD

* Depth (to top of sample) below logging reference at 548 ft. above mean sea level.

COLUMN HEADINGS AND ABBREVIATIONS:

Lithofacies:	Classification of Harvey et al., 1977.
%:	Percent of total sample represented by described lithology.
Bed Tk.:	Bed thickness. TKB=thick beds, >30 cm; MB=medium beds, 10-30cm; TNB=thin beds, 1-10cm; VTNB=very thin beds, <1 cm.
Grain Size:	Average grain size of rock, in Ø units.
Laminations, type:	E=even, parallel; DE=discontinuous, even parallel; DWN=discontinuous, wavy, non-parallel; MS=massive, nonlaminated.
Laminations, tk:	Thickness of laminae. VTKL=very thick, >30mm; TKL=thick, 10-30mm; ML=medium, 3-10mm; TNL=thin, 1-3mm; VTNL=very thin, <1mm.
Laminations, space:	Spacing of laminae; same abbreviations as for thickness.
Bioturb:	Bioturbation. 6=totally boiturbated; 5=very strongly bioturbated, but bedding is visible; 4=strongly bioturbated; 3=medium bioturbated; 2=weakly bioturbated; 1=sporadic burrows; 0=no bioturbation.
Pyrite nodules, size:	Size range in mm.
Pyrite nodules, dist.:	Distribution of nodules. BD=along bedding; BU=burrows; RN=random.
Pyrite nodules, ab.:	Abundance of nodules, as represented by approximate number counted on radiograph.

TABLE 2 - REVISED LITHOLOGIC CHARACTERIZATION, SANGAMON COUNTY, ILLINOIS, CORE SAMPLES

SAMPLE NUMBER	DEPTH* (FT)	FORMATION	LITHO-FACIES	%	BED TK.	GRAIN SIZE	MUNSELL COLOR	LAMINATIONS TYPE	LAMINATIONS TK.	LAMINATIONS SPACE	BIO-TURB.	SYNAERESIS EARLY	SYNAERESIS LATE	PYRITE NODULES SIZE	PYRITE NODULES AB.	PYRITE NODULES DIST
01IL01L2	1576.0	HANNIBAL SH.	IB	100	TKB	6	5GY4/1	MS			5			0- 0	0	
01IL03L1	1589.4	HANNIBAL SH.	IB	100	TKB	6	5GY4/1	MS			5			0- 0	0	
01IL04L1	1602.0	HANNIBAL SH.	IB	100	TKB	6	5GY4/1	MS			5			2-16	5	BU
01IL05L1	1615.1	HANNIBAL SH.	IB	100	TKB	6	5GY5/1	MS			5			2-16	5	BU
01IL06L1	1619.5	HANNIBAL SH.	IB	100	TKB	6	5GY4/1	MS			5	10		1- 1	5	BU
01IL07L1	1631.6	HANNIBAL SH.	IB	100	TKB	7	5GY4/1	MS			5			0- 0	0	
01IL07L2	1633.9	"GLEN PARK" FM.	DOL	75	MB	8	5Y6/1	MS			6			0- 0	0	
01IL07L2		"GLEN PARK" FM.	IA	25	TNB	8	5GY5/1	MS			6			0- 0	0	
01IL09L1	1647.4	SAVERTON SH.	IA	100	TKB	8	5GY4/1	MS			5	15		2- 4	7	BU
01IL09L2	1656.2	SAVERTON SH.	IA	100	TKB	8	5GY4/1	MS			4	5		1- 7	5	RN
01IL12L1	1678.6	SAVERTON SH.	IIA	100	TKB	8	5Y2/1	DEN	VTNL	TKL	4	3		1- 5	10	BD
01IL13L1	1688.0	SAVERTON SH.	IIA	100	TKB	8	5Y2/1	EN	TNL	THL	3			1- 1	25	BD
01IL14L1	1693.2	GRASSY CREEK SH	IIIA	60	TNB	8	5YR2/1	DE	TNL	HL	2			2- 5	20	BD
01IL14L1		GRASSY CREEK SH	IIA	40	TNB	8	5GY4/1	MS			3			2-10	5	BU
01IL16L1	1723.4	GRASSY CREEK SH	IVA	100	TKB	8	N2	E	VTNL	THL	0			1- 4	>25	BD
01IL18L1	1740.2	GRASSY CREEK SH	IVA	100	TKB	8	5YR2/1	E	TNL	TNL	0			2-10	5	RN
01IL19L1	1753.5	GRASSY CREEK SH	IVA	100	TKB	8	N2	E	VTNL	TNL	0			1- 3	20	BD
01IL20L1	1763.3	SWEETLAND CR.SH	IIIA	50	TNB	8	5YR2/1	E	TNL	TNL	0			2- 5	15	BD
01IL20L1		SWEETLAND CR.SH	IA	50	TNB	8	5GY5/1	MS			5	>25		0- 0	0	

* Depth (to top of sample) below logging reference at 595.9 ft. above mean sea level.

See Table 1 for column headings and abbreviations.

TABLE 3 - LOCATION OF NEW ALBANY SHALE (NAS) SAMPLES TAKEN FROM WELL CUTTINGS IN ILLINOIS (Note that several samples were taken from a single well)

Sample Numbers (NAS-)	County	Sec-T-R	Well Name
001-027	(various	locations)	outcrop samples
028-029	Clay	16-3N-6E	So. Ill. Oil #1 Mearns
030-032	Effingham	32-6N-5E	Juniper Petrl. 12x-32 Gerth
033-034	Jefferson	18-3S-1E	Dunnill #1 Kujawa
035-039	Madison	35-5N-7W	B. Hall #1 Wehling
040-043	Mason	3-19N-10W	Pinkston #1 Blessman
044-045	Washington	30-2S-3W	Amoco Prod. #1 Kolweier
046-047	Washington	27-3S-1W	Juniper Petrl. #24x-27 Kubiak
048-051	Washington	1-3S-4W	Anschutz #1 Elgenrauch
052-055	Wayne	27-1N-7E	Pure Oil #3 Billington
056-059	Wayne	14-1N-8E	Nation Oil #1 Van Fossan-Brown
060-063	Wayne	28-1S-6E	Texaco NCT-1 Fuhrer
064-068	Wayne	29-2S-9E	Collins Bros. #1 Hill
069-074	Wayne	4-3S-7E	Savage/Zephyr #1 Sprague
075-082	Wise, VA		
083-088	Christian	28-13N-1W	Union Oil #1 Cleveland
089-092	Gallatin	11-8S-10E	Humble Oil #33 Busiek-Crawford
093-097	Gallatin	29-9S-9E	Texaco Walters
098-102	Greene	32-11N-11W	Kewanee Oil #1 Eula
103-105	Lawrence	29-4N-12W	Atlantic Richfield #77 Lewis
106-107	Logan	7-19N-3W	Allspach #1 Park
108-112	Macon	33-18N-2E	Hill #1 Haynes
113-117	Pope	10-13S-6E	Williams #1 Austin
118-121	Saline	34-10S-6E	Texas Pacific #1 Wells
122-126	Saline	32-10S-7E	Texota Oil #1 King
127-133	Wabash	9-1S-12W	So. Triangle Oil #D2 Zimmerman
134-135	Woodford	28-27N-3W	Centrl. Ill. Light #C18 Cilco
136-138	Champaign	12-22N-11E	Peoples Gas #1 Condit
139-141	Christian	25-11N-1E	Franks Petrl. #1 Wagner
142-146	Clay	11-2N-5E	Keystone Oil #1 Woomer-Campbell
147-149	Clark	4-10N-11W	Corley #1 Miller
150-151	Coles	27-12N-7E	Energy Prod. #G-1 Arterburn
152-155	Coles	20-14N-7E	Brehm #1 Lambert
156-157	Crawford	2-5N-11W	Bell #1 Miller
158-161	Crawford	12-5N-14W	Doheny #1 Arnold
162	Crawford	36-6N-11W	Slape Drilling #1 Kincaid
163	Crawford	6-7N-11W	K Oil #1 Mehler
164-165	Crawford	12-7N-11W	W Drilling #1 Brown
166-167	Crawford	31-7N-13W	Ill. Oil Invest #1 Mallory et al.
168-170	Cumberland	4-10N-9E	Texaco #1 McCandlish
171-174	De Witt	1-20N-4E	Peoples Gas #1 Lamb
175-176	Edgar	4-14N-14W	Jones-Simpson Drill. #1 Steele-Moss
177-178	Edgar	1-14N-14W	Wansan Petrl. #1 Sims
179-181	Effingham	3-7N-7E	Energy Res. #1 Niemerg
182-186	Hamilton	1-4S-5E	Kewanee Oil #1 Wellen
187-190	Hamilton	13-6S-5E	Shell Oil #4 Mohave
191-193	Hamilton	6-6S-7E	Texaco #1 Cuppy

TABLE 3 - CONTINUED

Sample Numbers (NAS-)	County	Sec-T-R	Well Name
194-196	Iroquois	21-24N-13W	Peoples Gas #1 Mumm
197-199	Iroquois	13-25N-11W	Peoples Gas #1 Keen
200-203	Jasper	1-8N -8E	Total Leonard #1 Thoele
204-206	Jefferson	32-4S-3E	Juniper Petrl. #33x-32 Hayse
207-208	Lawrence	9-3N-11W	Shellensker Drill. #1 Seward
209	Madison	23-4N-5W	Stocker & Sitler #1 Suess
210-212	Marion	35-3N-2E	Brehm Drill. #1 Behnke
213-215	Lawrence	25-3N-13W	Highland Oil #1 Hobbs
216-217	McDonough	23-4N-2W	Bur-Kan Petrl. #1 Chipman
218-220	McLean	33-23N-2E	Zimmerman #1 McLean Co.
221-225	McLean	31-23N-3E	Union Hill Gas #1 Bozarth
226-227	McLean	26-23N-6E	Garland & Hoover #1 Green
228-230	Piatt	13-21N-6E	Union Hill Gas #1 Buchan
231-233	Sangamon	11-15N-3W	Corley #1 Anderson
234-235	Sangamon	1-16N-6W	Caney Oil #1 Eugene
236-238	Vermillion	12-19N-11W	Allied Chem. #1 Allied Chem.
239-240	Vermillion	10-23N-11W	Peoples Gas Layden
241-243	Vermillion	15-23N-14W	Peoples Gas #1 Swanson
244-250	White	23-6S-9E	Haley Prod. #1 Trainor
251-253	Williamson	25-8S-3E	Brehm Drill. #1 Harris Unit
254-257	Macoupin	23-12N-6W	Crown II Mine (Penn. samples)
258-260	Williams	17-9S-4E	Amax-Delta Mine (Penn.samples)
261-264	Gallatin	14-10S-8E	Eagle Strip Mine (Penn.samples)
291-294	Bond	12-5N-4W	Texas Co. #1 Sybert
295	Champaign	33-17N-9E	Beatty #Bozdeck
296-299	Champaign	23-19N-10E	Peoples Gas #1 Tracy
300-303	Champaign	19-19N-8E	Vickery Drilling Co. B-0-1
304-307	Clark	33-11N-14W	Fanchot #A-1 Elliott
308-309	Clay	16-3N-5E	Southern Ill. Oil Prod. #1Father.
310	Clay	15-2N-7E	Steele #1 Leak
311-314	Coles	16-13N-9E	Union Oil of Calif.#1 Moler
315-318	DeWitt	16-11N-3W	Harris #1 Lewis
319-321	Douglas	31-16N-8E	Cabot Corp. #2 Cabot-Tuscola
322	Douglas	2-14N-10E	Joe Beckner Drill. #1 Jividen
323-327	Fayette	21-6N-2E	Brehm #1 Ireland
328-331	Fayette	31-5N-3E	Shell Oil #1 Ford
332-335	Franklin	36-6S-2E	Shell Oil #19 C.W.& F. Coal
336-339	Franklin	19-7S-2E	Gallagher #1 Zeigler Coal & Coke
340-343	Franklin	20-6S-4E	Texaco #1 U.S. Steel
344-346	Jackson	36-9S-2W	Grummer #1 Dickerson
347-348	Jackson	11-7S-2W	Texaco #1 Harsha
349-352	Jackson	21-10S-3W	National Assoc.Pet.Co. #1 Hays
353-356	Jefferson	28-3S-2E	Crystal Oil Co. #1 Storey
357	Montgomery	8-7N-2W	Calvert Drill, #1 Blackburn
358-360	Johnson	34-13S-3E	Texas Pacific Oil #1 Farley
361-363	Knox	2-11N-2E	Illinois Power G-2
364-366	Macon	36-16N-1E	Corley #1 Hill
367-369	Macoupin	19-12N-6W	Wright #1 Thoron
370-372	Marion	25-4N-3E	Total Leonad #1-25 Lane
373-377	Montgomery	11-9N-3W	Mobil Oil Co. #1 Dewerff
378-380	Montgomery	33-12N-5W	Phillips Pet. Co. #5 Farmersvl.

TABLE 3 - CONTINUED

Sample Numbers (NAS-)	County	Sec-T-R	Well Name
381-383	Morgan	15-13N-8W	Panhandle E. Pipe Line Co. #7-15 Whitelock
384	Moultrie	7-15N-6E	Felmont Oil Corp. #1 Ware
385-386	Perry	19-5S-2W	Total Leonard Inc. #1 Pick
387-390	Piatt	5-19N-5E	Texaco #1 Irenchard
391-397	Saline	8-10S-5E	Parker #1 Parker
398-404	Saline	9-9S-5E	Brehm Drill. & Prod. #1 Ozment
405-407	Shelby	17-9N-3E	Energy Resources of Ill. #1 Gregg
408-411	Shelby	3-10N-5E	Total Leonard Inc. #1 Engel
412-414	Tazewell	36-24N-7W	Central Ill. Light #1 Rutherford
415	Shelby	17-9N-3E	Total Leonard Inc. #1 Engel
416-418	Union	12-12S-11W	Fry #1 Hill
419-425	Wayne	21-1S-9E	Luttrell #1 Fetherling
426-432	White	21-3S-9E	National Oil Co. #1 Granger
433-438	Crittenden, Ky		Shell Oil #1 Davis
439	Johnson	8-12S-3E	Outcrop sample (Penn.)
440	Union	25-11S-1E	Outcrop sample (Penn.)
441-444	Clinton	6-2N-4W	Anschutz #1 Schroder
445-451	Jasper	17-5N-10E	Pure Oil Co. #A-5 Honey
452-454	Mason	9-22N-7W	Engelke #1 Woodrow
455-459	Montgomery	11-8N-5W	Calif. Co. #1 Schmidt
460-462	Peoria	25-11N-8E	Prentiss #1 Coon
463-465	Pike	33-3S-4W	A. W. Neal Co. #1 Crump
466-468	Pike	23-6S-3W	Texaco #1 Scott
469-471	Schuyler	11-1N-3W	Kerwin #1 Wrench
472-477	White	15-5S-9E	Brehm #1 Reinwald
478-486	Effingham	15-6N-6E	Kingwood Oil #1 McWhorter
487-504	Hamilton	6-6S-7E	Texaco #1 Cuppy
505-521	Pope	2-11S-6E	Texas Pacific #1 Streich Comm.

TABLE 4 - LOCATION OF NEW ALBANY SHALE (NAS) SAMPLES OBTAINED FROM WELL CUTTINGS IN INDIANA (Courtesy of the Indiana Geological Survey)

Sample Numbers (NAS-)	County	Sec-T-R	Box Numbers
265	Daviess	16-3N-7W	9806
266	Spencer	3-6S-4W	9684
267	Fontain	33-22N-7W	4754
268	Lawrence	20-5N-2E	6088
269	Martin	5-3N-4W	3577
270	Sullivan	14-8N-8W	7029
271	Posey	18-5S-13W	9339
272	Sullivan	36-7N-10W	8080
273	Harrison	2-6S-4E	7358
274	Crawford	18-3S-1W	10437
275	Putnam	12-12N-3W	5411
276-281	Elkhart		500-595
282	Warrick	36-4S-9W	3951
283	Montgomery	14-17N-3W	4969
284	Vermillion	27-14N-9W	10060
285	DeKalb	8-35N-14E	7177
286	Sullivan	32-8N-8W	3274
287	Owen	14-9N-5W	6561
288	Morgan	3-12N-1W	6752
289	Hendricks	12-14N-1E	6069
290	Washington	17-2N-5E	10021

TABLE 5 - CLAY MINERALOGY, DRILL CUTTING SAMPLES

Sample Number	Clays (parts/10)			
	Illite	Expandables	Kaolinite	Chlorite
NAS - 034*	5.5	2.5		2
037*	5.5	2		2.5
167	5	2.5	1	1.5
206	6.5	1.5		2
227	5	2	0.5	2
230	6	2		2
294	6.5	2	0.5	1
299	5.5	2		2.5
303	5	3	0.5	2
308	6.5	2.5		1.5
320	6.5	1.5		2.5
322	5.5	2.5	0.5	1.5
327	6	2		2
330	4	3.5	0.5	2
341	5.5	3		1.5
349	6	1.5		2.5

*revised data (original data reported in the October 1978 report).

TABLE 6 - CLAY MINERALOGY, DRILL CUTTING SAMPLES

Sample Number	Clays (parts/10)			
	Illite	Expandables	Kaolinite	Chlorite
NAS - 124	9	1		0.1
131	5.5	4.5		0.1
134	5.5	2		2.5
135	5.5	1	1	2.5
138	5.5	1	0.5	2.5
141	5	2.5		2.5
144	5.5	3		1.5
145	6	2		2
148	5.5	2.5		2
151	5.5	2		2.5
154	5.5	2		2.5
157	5.5	2.5		1.5
160	6	2		2
161	6	2		2
162	6	2	0.5	1.5
164	4	3	1	2
166	6	2.5		1.5
169	4	3.5	0.5	2
176	5	2.5		2
178	5.5	1.5		2.5
181	5.5	2		2
186	5.5	2.5		1.5
192	6.5	2.5		1.5
195	4	4	0.5	2
196	5.5	2		2.5
199	6	1.5		2.5
202	5.5	2.5		2.5
213	5	3	0.5	1.5

TABLE 7 - CLAY MINERALOGY, DRILL CUTTING SAMPLES

SAMPLE NUMBER	DEPTH	ILL	CHL	KAO	EXP
NAS- 034		5.0	2.0	0.0	3.0
NAS- 037		5.5	2.0	0.0	2.5
NAS- 085		5.0	3.0	0.0	2.0
NAS- 090		6.5	1.5	0.0	2.5
NAS- 092		6.0	1.5	.5	2.0
NAS- 104		8.5	.1	0.0	1.5
NAS- 110		4.5	2.0	.5	2.5
NAS- 111		4.0	1.5	1.0	3.5
NAS- 114		6.5	.5	.5	2.5
NAS- 115		6.0	1.5	.5	2.5
NAS- 116		6.0	1.5	0.0	2.5
NAS- 117		8.0	.1	0.0	2.0
NAS- 119		7.5	.1	0.0	2.5
NAS- 120		7.0	1.0	0.0	2.5
NAS- 121		6.5	1.0	0.0	2.0
NAS- 123		6.5	.5	0.0	2.5
NAS- 125		7.0	.1	0.0	3.0
NAS- 126		8.0	.1	0.0	2.0
NAS- 129		7.0	.5	0.0	2.0
NAS- 130		5.0	1.0	.1	4.0

TABLE 8 - VITRINITE REFLECTANCE, DRILL CUTTING SAMPLES

Sample Numbers (NAS-)	Readings	Ro(%) Average	Std. Deviation
208	50	0.50	0.06
211	47	0.58	0.07
213	46	0.63	0.10
256	52	0.50	0.04
259	51	0.65	0.05
260	50	0.64	0.05
261	56	0.67	0.05
262	50	0.74	0.08
263	55	0.80	0.06
264	50	0.72	0.08
265	45	0.58	0.10

TABLE 9 - MEAN-RANDOM VITRINITE REFLECTANCE, DRILL CUTTING SAMPLES

API NUMBER	SAMPLE NUMBER	N	R_0	STD DEV	<.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	>1	VITRAIN BAND
					PERCENT VITRINITE IN EACH REFLECTANCE CLASS																	
1218526176	NAS 131	35	.62	.07	0	0	0	0	0	9	9	14	14	37	17	0	0	0	0	0	0	
1203330012	NAS 166	30	.59	.07	0	0	0	0	3	7	20	30	23	10	3	3	0	0	0	0	0	
1204922476	NAS 180	46	.56	.06	0	0	0	0	0	15	30	33	11	7	4	0	0	0	0	0	0	
1206501276	NAS 186	27	.70	.09	0	0	0	0	0	0	0	15	11	37	7	11	4	15	0	0	0	
1206500760	NAS 190	43	.68	.08	0	0	0	0	0	0	2	12	21	26	19	7	9	5	0	0	0	
1207500996	NAS 196	40	.52	.08	0	0	0	3	15	25	20	18	15	5	0	0	0	0	0	0	0	
1207501015	NAS 198	51	.48	.07	0	0	0	10	25	20	25	20	0	0	0	0	0	0	0	0	0	
1207922576	NAS 201	42	.75	.09	0	0	0	0	0	0	0	5	10	14	21	26	12	7	2	2	0	
1208122946	NAS 205	51	.66	.08	0	0	0	0	0	0	6	12	29	29	8	4	6	6	0	0	0	
1210127798	NAS 207	50	.57	.09	0	0	0	2	6	18	16	16	18	14	6	4	0	0	0	0	0	

TABLE 10 - MEAN-RANDOM VITRINITE REFLECTANCE, DRILL CUTTING SAMPLES

API NUMBER	SAMPLE NUMBER	N	R_0	STD DEV	<.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	>1	VITRAIN BAND
					PERCENT VITRINITE IN EACH REFLECTANCE CLASS																	
1201901424	NAS 137	21	.45	.06	0	0	5	14	19	43	14	5	0	0	0	0	0	0	0	0	0	
1201922776	NAS 140	50	.52	.08	0	0	0	6	10	22	32	8	14	6	2	0	0	0	0	0	0	
1202501447	NAS 143	36	.53	.09	0	0	0	3	11	31	17	14	14	8	3	0	0	0	0	0	0	
1202922459	NAS 151	48	.62	.10	0	0	0	0	0	8	13	25	25	6	6	8	8	0	0	0	0	
1202501447	NAS 146	44	.63	.06	0	0	0	0	0	2	7	20	32	25	9	5	0	0	0	0	0	
1202922450	NAS 155	24	.54	.07	0	0	0	0	4	21	33	17	21	4	0	0	0	0	0	0	0	
1203300524	NAS 156	27	.49	.07	0	0	4	11	11	26	30	11	4	4	0	0	0	0	0	0	0	
1203302498	NAS 162	46	.55	.08	0	0	0	2	7	15	33	20	7	11	7	0	0	0	0	0	0	
1203900391	NAS 173	50	.49	.07	0	0	0	10	12	34	16	20	8	0	0	0	0	0	0	0	0	
1204500966	NAS 177	31	.50	.06	0	0	0	3	13	35	26	19	3	0	0	0	0	0	0	0	0	

TABLE 11 - CORRECTED MEAN-RANDOM VITRINITE REFLECTANCE, DRILL CUTTING SAMPLES

API NUMBER	SAMPLE NUMBER	N	R_0	STD DEV	<.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	>1	VITRAIN BAND
					PERCENT VITRINITE IN EACH REFLECTANCE CLASS																	
1216700115	01IL11L1	29	.43	.07	0	0	17	10	24	34	7	3	3	0	0	0	0	0	0	0	0	
1216700115	01IL14L1	33	.45	.07	0	0	15	9	18	36	6	15	0	0	0	0	0	0	0	0	0	
1216700115	01IL16L1	44	.43	.07	0	0	16	18	20	25	14	7	0	0	0	0	0	0	0	0	0	
1216700115	01IL17L1	31	.44	.10	0	0	19	16	23	16	6	6	10	3	0	0	0	0	0	0	0	
1216700115	01IL19L1	39	.45	.07	0	0	3	10	41	31	3	8	3	0	3	0	0	0	0	0	0	
1216700115	01IL21L1	22	.38	.05	0	0	18	41	36	5	0	0	0	0	0	0	0	0	0	0	0	
1205101324	07IL03L1	39	.48	.11	0	0	10	15	21	15	10	8	13	5	3	0	0	0	0	0	0	

PLATE 1 - SCANNING ELECTRON MICROGRAPHS

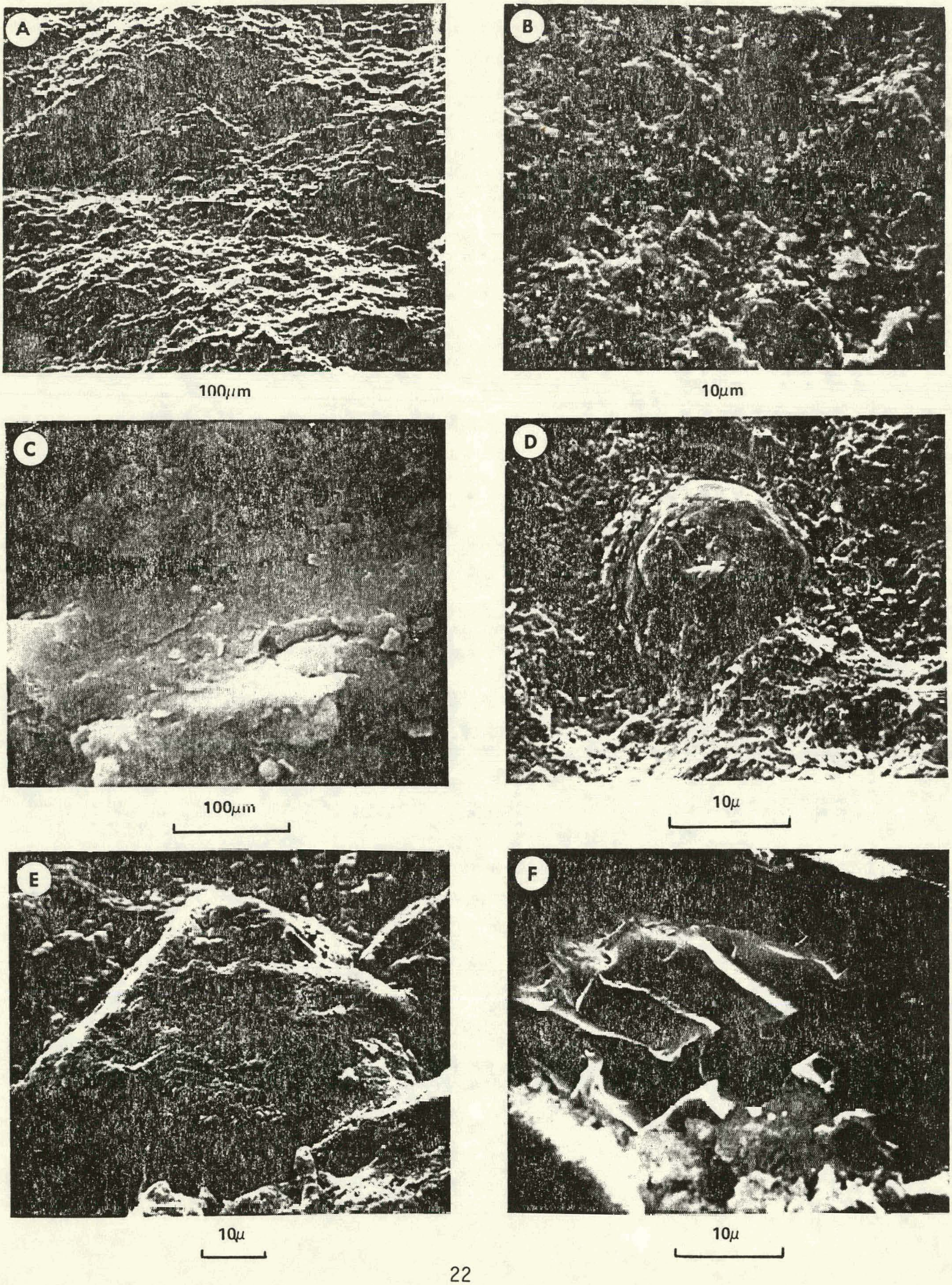


PLATE 1 - SCANNING ELECTRON MICROGRAPHS

A. Fracture surface cutting across the bedding planes. Linear features result from clay flake orientation parallel to bedding. 01KY2PL1, a sample which fractured at 2.09 mega pascals in the point load test, magnified 110X.

B. Photomicrograph looking down onto bedding plane surfaces exposed by fracturing. Relatively flat surfaces of illite flakes are visible. 01KY01L1, magnified 510X.

C. Photomicrograph of the surface texture of an illite flake. 01KY06C1, magnified 2290X.

D. Pyrite sphere surrounded by clay flakes. 01KY03L1, magnified 220X.

E. Dolomite rhombohedron with associated quartz. Sample 04IL30C1, polished and etched with HF acid, magnified 1160X.

F. Organic particle. Sample 04IL30C1, polished and etched with HF acid, magnified 2070X.

PHYSICAL CHARACTERIZATION

Introduction

The project is a study of the index properties, directional properties, and strength of oriented core of Devonian black shale from the Illinois Basin. Index properties include moisture content, specific gravity, bulk density, and Shore hardness. Directional seismic velocities will be determined with an acoustical bench. Strength tests include point load fracture strength and indirect tensile strength (Brazilian split). Fracture frequency, drilling rate, and core recovery are also compiled as an additional mechanical index.

Results

Summary

Physical testing of oriented cores 01KY, 02IL, 04IL, and 06IL is complete. Point load test results for core 06IL are presented to update a map showing point load fracture frequency and location for each of the tested cores (fig 1). A comprehensive report of physical index properties for core 01KY is presented in Table 1.

Core 11IL Progress

Processing of core 11IL from Hardin Co., Illinois, is under way. Preliminary investigation has identified several features of importance to the physical characterization of the core. The most apparent feature of the core is that it is not intact rock. Natural fractures occur throughout the core. Two distinct fracture sets cut across the bedding and a third dominant orientation of natural fractures occurs parallel to the bedding. Fractures parallel to the bedding probably represent relief to a stress normal to the bedding. This type of fracture response may have been enhanced by the coring operation. Various subvertical fractures at other orientations are common. Secondary mineralization is common along fracture sufaces. Minor auto-breccias and offset bedding indicate displacement and faulting along fractures.

It is anticipated that fractures and fracture related irregularities within the rock will control the rocks mechanical behavior. The core does not contain two-inch intervals of intact rock required for mechanical test specimens, due to the density of fractures. The extent to which mineralization has healed fractures is not known. For this reason a detailed structural description of the core is being emphasized. Modifications of mechanical testing procedures may be necessary.

The difficulty of orienting core intervals of poor rock quality is remedied by orienting the core relative to the strike and dip of the bedding. The strike and dip of the bedding, measured by a core orienting device over relatively intact intervals of core, is approximately $143^{\circ}/12^{\circ}$ NE.

Shore hardness values for the 11IL core are significantly higher than values obtained on previously tested New Albany Shales of the Illinois Basin. Adjusted values range from 60 to 120.

Fig. 1 Summary of point testing results for cores 01KY, 02IL, 04IL, 06IL. Frequency of point load fractures is plotted on map showing locations of test cores and wells used in this study. Contours show elevation (in feet) of the base of the New Albany Shale Group (after Swann and Bell, 1958, Fig. 2)

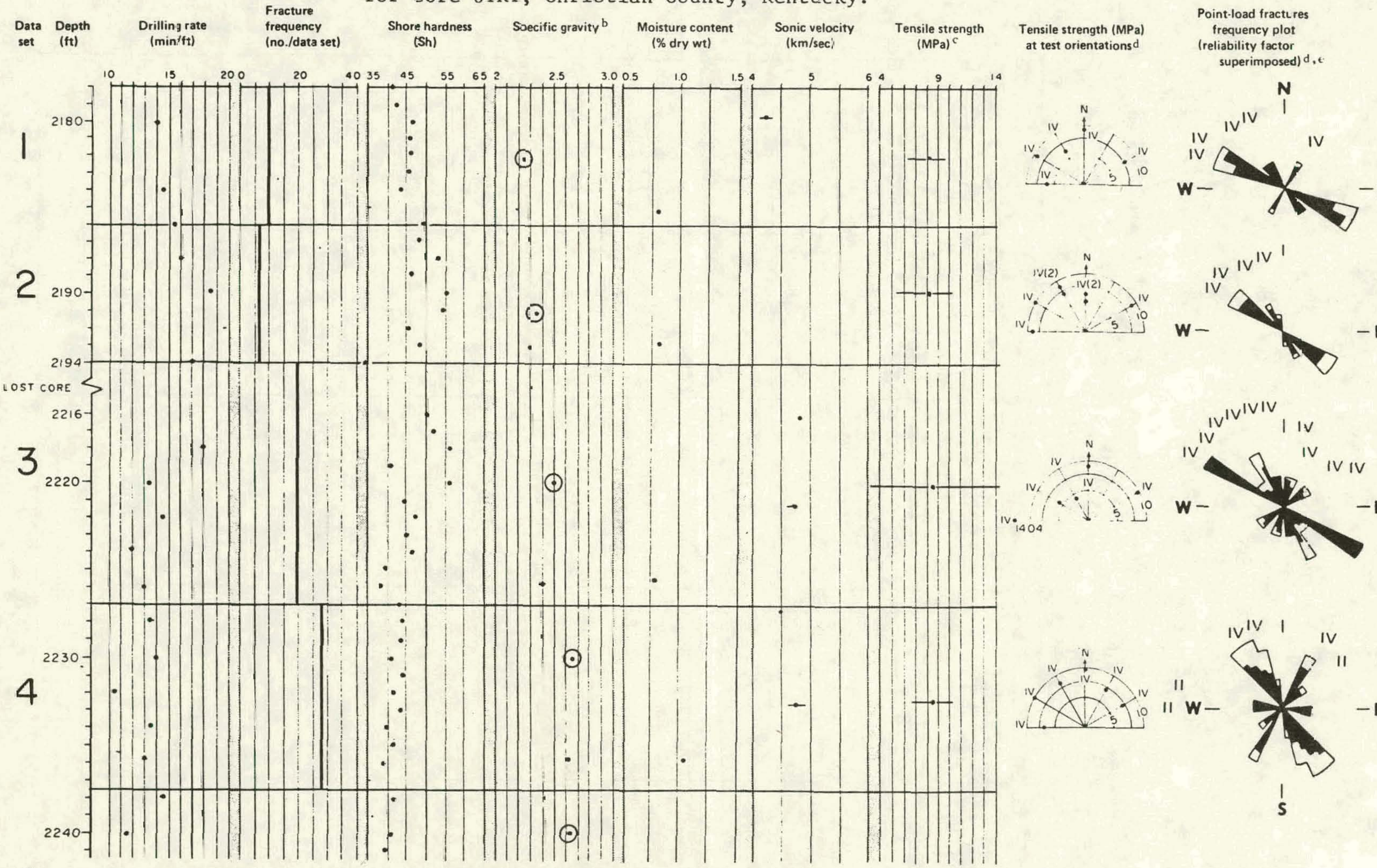
Explanation of Table 1

Results are reported for data sets of core of approximate 10 foot lengths which correspond to divisions of the core that are used in associated projects in this investigation. Point Load Strength Index values are not included in the table because average values computed from individual tests are not representative. This is due to the extremely variable failure behavior exhibited by different point load samples. Tensile strength values in Table 1 are Brazilian split results.

An addition to point load fracture frequency results for this core is shown in Table 1. A numerical "reliability factor" was assigned to each point load test and these values are incorporated into fracture frequency data to generate the second frequency diagram. In testing a natural material such as shale, flaws and irregularities inherent in a sample may influence its mechanical test behavior such that it is not representative of the in-situ rock unit. Flaws and irregularities may include pyrite nodules, scribe grooves, fossils, slaking, slickensiding, jointing, etc., or such things as uncertainty of orientation of the sample, or movement of the sample during testing. A "reliability factor" was used to assign a value to the degree of influence of any of these features so that a comparison of test results for different samples could be made that would include a measure of these types of influences in order to represent the strength characteristics of the actual rock unit in question.

An integral value between 1 and 10 was assigned for a reliability factor. A test in which specimen flaws were minimal and in which the sample did not move appreciably prior to failure, received a reliability factor of 10. A test in which flaws were suspected of influencing failure behavior of the sample received a lesser reliability factor. To remove arbitrariness specific types of flaws were given values to subtract from 10. The reliability data were utilized as multiplying factors for point load data; fractures produced in "reliable" tests were recorded as one in the orientation in which they were formed in the sample, and values of fractures produced in "less reliable" tests were recorded as a percentage of one in the orientation in which they were formed in the sample.

TABLE 1. Physical index properties and mechanical test results for core 01KY, Christian County, Kentucky.[a]



[a]Natural fracture data included in summary only because of scarcity of data.

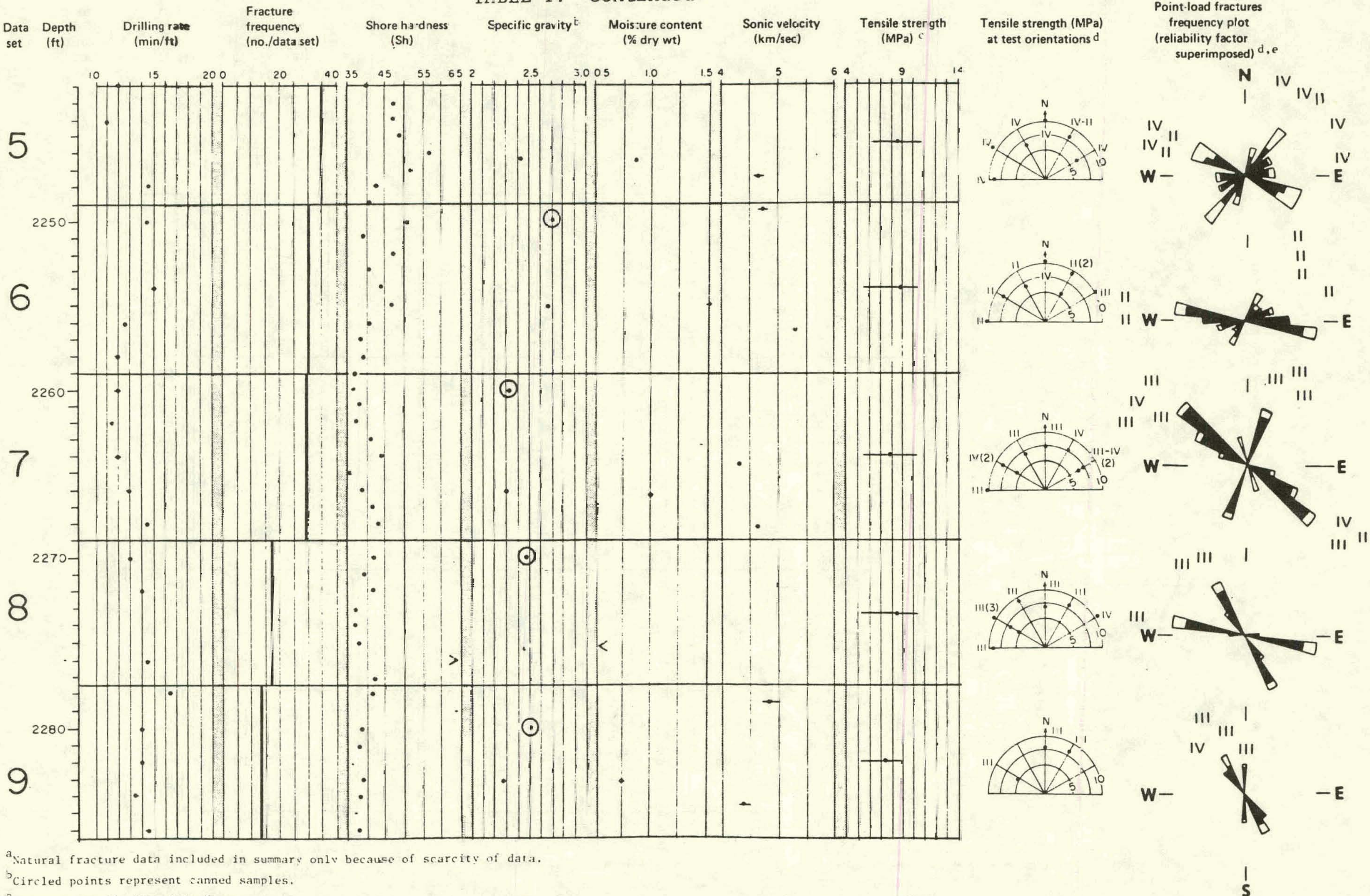
[b]Circled points represent canned samples.

[c]Indirect-tensile "Brazilian" test.

[d]Numerals I, II, III, and IV represent lithofacies of the New Albany Shale defined in ISGS annual report, September 30, 1977, submitted to ERDA, contract E-(40-1)-5203.

[e]Unshaded rosette represents fracture data without "reliability factor"; shaded rosette represents fracture data with "reliability factor" incorporated.

TABLE 1. *Continued.*[a]



[a]Natural fracture data included in summary only because of scarcity of data.

[b]Circled points represent canned samples.

[c]Indirect-tensile "Brazilian" test.

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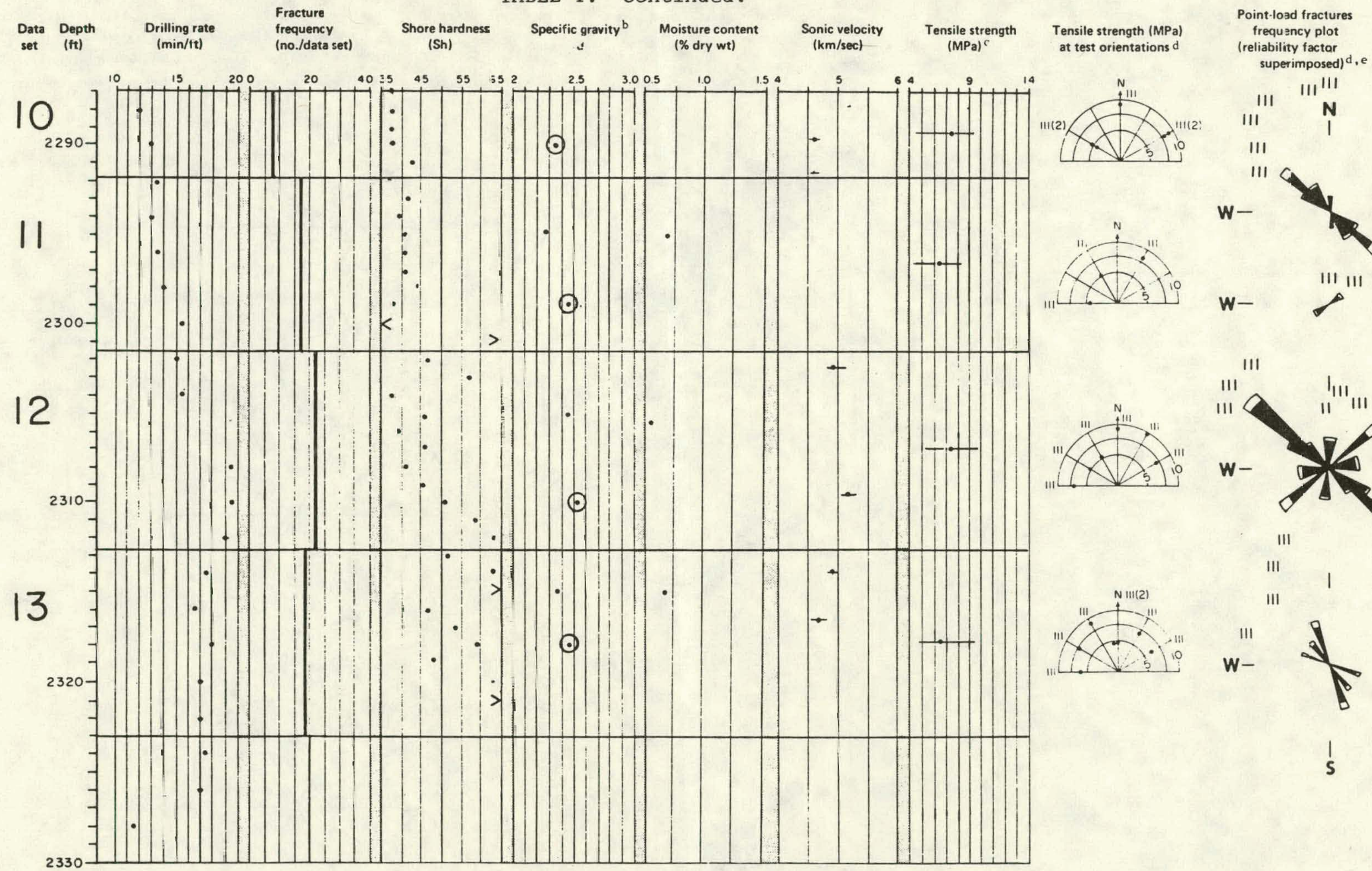
[e]Unshaded rosette represents fracture data without "reliability factor"; shaded rosette represents fracture data with "reliability factor" incorporated.

TABLE 1. *Continued.*[a]



SUMMARY FOR CORE 01KY	14.63 (min/ft)	20 per data set	45.6	2.44	0.81%	4.72 km/sec	7.85 2 MPa	(following page)

[a]Natural fracture data included in summary only because of scarcity of data.

[b]Circled points represent canned samples.

[c]Indirect-tensile "Brazilian" test.

[d]Numerals I, II, III, and IV represent lithofacies of the New Albany Shale defined in ISGS annual report, September 30, 1977, submitted to ERDA, contract E-(40-1)-5203.

[e]Unshaded rosette represents fracture data without "reliability factor"; shaded rosette represents fracture data with "reliability factor" incorporated.

Summary of physical index properties and mechanical test results for 01KY—*Continued*.

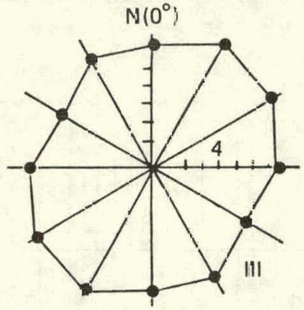
TENSILE STRENGTH AT TEST ORIENTATION

LITHOLOGY III

Number of samples/
average tensile strength

-60°	-30°	0°
8/6.32	5/7.54	7/7.38

30°	60°	90°
4/8.38	7/8.19	5/7.45

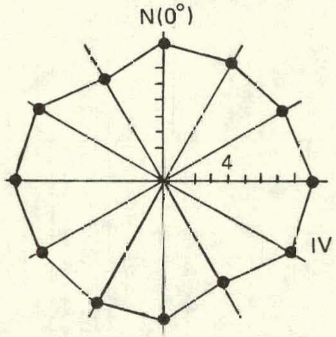


LITHOLOGY IV

Number of samples/
average tensile strength

-60°	-30°	0°
7/8.76	6/7.10	6/8.41

30°	60°	90°
3/8.24	7/8.49	5/9.08

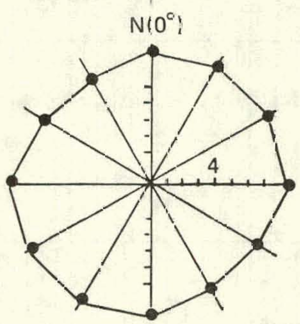


CORE 01KY

Number of samples/
average tensile strength

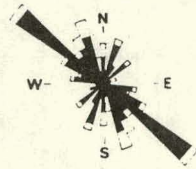
-60°	-30°	0°
15/7.52	12/7.23	14/8.04

30°	60°	90°
9/8.19	14/8.34	11/8.43

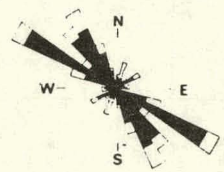


POINT-LOAD FRACTURE ORIENTATION

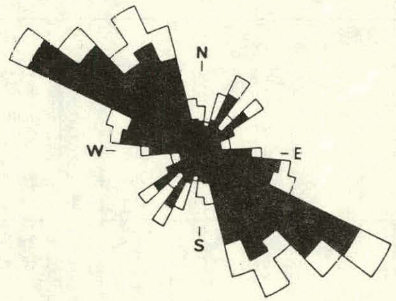
LITHOLOGY III
46 samples



LITHOLOGY IV
49 samples

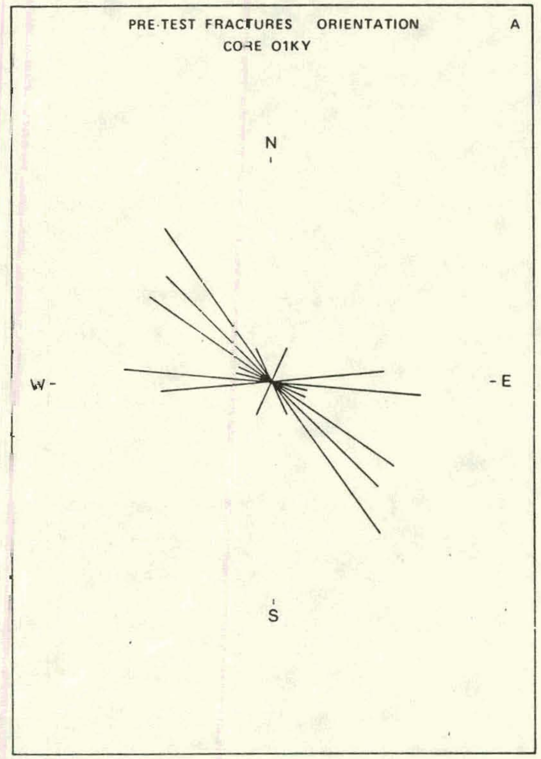


CORE 01KY
105 samples



NATURAL FRACTURES

(Frequency plot)



[a]Natural fracture data included in summary only because of scarcity of data.

[b]Circled points represent canned samples.

[c]Indirect-tensile "Brazilian" test.

[d]Numerals I, II, III, and IV represent lithofacies of the New Albany Shale defined in ISGS annual report, September 30, 1977, submitted to ERDA, contract E-(40-1)-5203.

[e]Unshaded rosette represents fracture data without "reliability factor", shaded rosette represents fracture data with "reliability factor" incorporated.

GEOCHEMICAL CHARACTERIZATION

QUANTITATIVE DETERMINATION OF MAJOR, MINOR, AND TRACE ELEMENTS IN SHALES

Introduction

Determine not less than 49 major, minor, and trace elements in 300-500 shale samples, which are representative cross sections of the cores taken. Include organic and mineral carbon; total hydrogen; total sulfur and when that exceeds 0.5%, pyritic and sulfate sulfur. Also, report other elements observed during normal routine analysis. The data generated will be used to evaluate: 1) the potential economic importance of trace element concentrations in organic-rich shales, 2) new geochemical exploration techniques for natural gas, 3) trace element enrichment in shale organic matter, 4) the occurrence of heavy metal sulfides in shales, 5) potential catalytic effects of trace elements on shale pyrolysis yields, and 6) potential disposal problems.

Elemental Analysis

Progress

Analyses of shale samples on hand is continuing satisfactorily. Of 243 samples received for complete analysis for major, minor and trace elements, analytical work has been completed on some 192, and the data are being tabulated and checked for inclusion in a future report.

INORGANIC/ORGANIC ASSOCIATIONS OF TRACE ELEMENTS IN BLACK SHALES

Introduction

Develop chemical and/or physical methods for the separation of the organic and inorganic phases of shales, and determine the trace elements that are associated with each phase. Methods tested include float-sink gravity separations, mechanical separations (Humphrey Spiral), acid extractions, and zonal centrifugation. Compare results of analyses for ten shales, their gravity fractions, and their separated organic phases to determine the elements closely associated with organic matter. Separation procedures that are most promising will be used to study further the organically combined trace elements in additional shale samples. This research is designed to yield new information concerning chemical variations in shale organic matter, which is the shale component about which little is known and which may be the most characteristic feature of gas bearing shales.

Progress

Kerogen products obtained from the acid-demineralized Christian Co, Ky and Effingham Co., Ill. cores are still undergoing analysis. However, preliminary data given in the accompanying table show that only the alkali elements exhibit concentrations that can be explained by the presence of residual ash. All other elements have concentrations in the kerogen well in excess of any contribution by unremoved mineral matter. Of the elements shown here, only bromine shows concentrations in the kerogen sufficiently high to account for all of the bromine in the whole shale.

Because these shales are only marginal gas producers, at best, few if any conclusions can yet be drawn concerning the relationship between trace element concentrations and gas production. The remaining data for these two samples will soon be available; however, until a number of shales from high gas-producing regions become available for testing, it will be difficult to draw meaningful conclusions.

Testing on the gradient density equipment is continuing in order to optimize the separation procedure. It is expected that some data will be available for the next reporting period.

Table 1. Trace Element Analyses of Shale and Kerogen Freed from it by Acid Demineralization

	Christian Co., Ky. S0001		Kerogen C-20395	Effingham Co., Ill S00056		Kerogen C-20441
K	2.92 %	*(58) ppm	7	3.48 %	(104) ppm	12 ppm
Na	.55 %	(11)	12	.49 %	(15)	6
As	68 ppm	(.14)	0.6	37 ppm		1.0
Br	5	(.01)	57	3	(.01)	247
Eu	1.6	(.003)	.23	1.5	(.005)	.09
Ga	17	(.03)	2.9	24	(.07)	1.3
La	35	(.07)	2.7	38	(.11)	1.1
Mo	180	(.36)	15	90	(.27)	5
Sb	6.1	(.01)	6	4.2	(.01)	3
Sm	9.1	(.02)	.86	10	(.03)	.3
U	61	(.12)	1.6	29	(.09)	.7
Yb	2.3	(.005)	1.2	2.3	(.007)	.8
Zn	72	(.14)	4.7	190	(.57)	6.3
Ash content			.2 %			.3 %

* The figures in brackets represent the contribution to the trace element concentration of the kerogens if the ash content is unremoved mineral matter.

MODE OF OCCURRENCE AND RELATIVE DISTRIBUTION OF HYDROCARBON PHASES IN SHALE

Introduction

Determine the character of off-gases from approximately 10-foot intervals in cores collected in the Illinois Basin. In addition, determine the relative distribution of hydrocarbons in ten specially prepared core samples, which are the same as those in previous unit. Preserve the samples in airtight containers and subsequently analyze them for evolved gases; highly volatile, low-molecular weight liquids; medium-volatile hydrocarbons; and solvent-extracted, low volatile hydrocarbons using GC-MS methods. Determine non-volatile, high-molecular weight hydrocarbons by GC analysis of shale pyrolytic products.

Determine the carbon isotopic composition of methane in off-gases from core samples whenever sufficient methane can be collected. Compare this data to other pertinent data such as gas composition and vitrinite reflectance for the purpose of making interpretations as to the origin and maturity of the gas. Perform laboratory experiments to study the relative effects and significance of chemical and isotopic fractionation that occurs as gas is released from core samples.

Data accumulated can be evaluated to gain a better understanding of the origin, migration, and location of natural gas associated with the shales.

Progress

Released Gas Analysis

Due to a number of problems encountered in coring the Hardin County, Illinois well only 22 samples were taken for released gas analysis.

The samples (approximately 4 inches in diameter by 4 to 5 inches in height) were sealed in aluminum canisters as soon as feasible after the core was brought to the surface. The samples were transported to the laboratory and are stored in a constant temperature (20°C) room. The temperature at the well site varied from approximately 4° to 8°C during the coring period. There was an initial build-up of pressure in the cannisters of 2 to 5 cm. of mercury. Most of the pressure increase can be attributed to the temperature change. After an equillibration period of 4 weeks, the pressure inside the canisters is less than the initial readings.

Preliminary gas chromatographic analysis of the head space gas of the first ten samples shows only the presence of carbon dioxide, nitrogen and oxygen. There is an increase in the amount of carbon dioxide present and a slight decrease in the amount of oxygen present compared to that normally found in the atmosphere. This may indicate that some oxidation is taking place.

Volatile Hydrocarbon Analysis

No new analyses for volatile hydrocarbons were made during this quarter.

Medium Volatile Hydrocarbon Analysis

Pyrolysis

The pyrolysis - gas chromatography technique discribed in the last quarterly report has been used to analyze for medium and low volatile organics in a total of eight black shale samples during this quarter. The samples were pyrolyzed at 250°, 350°, 550° and 750°C. The total pyrolysis time at each temperature was 5 seconds.

The eight samples pyrolyzed were S00060, The Indiana Standard; S00095, The Ohio Standard; 01KY07C1, 01KY12C1 and a composite of 01KY01L1 and 01KY05L1 from the Kentucky well; 02IL04C1 Effingham Co. well; and 06IL19C1 and 06IL20C1 from the Tazewell County, Illinois well.

The results of the pyrolysis-gas chromatography of the shale samples are shown in Tables 2 to 9 and Figures 1 to 8 inclusive. Comparisons are drawn on the basis of the relative amounts of hydrocarbon evolved at each pyrolysis temperature after grouping the hydrocarbons according to carbon number. No firm conclusions have been derived at this time.

Solvent Extraction

Six black shale samples have been extracted with a 70:30 (V:V) mixture of benzene: methanol in a soxhlet extraction apparatus. Each sample was extracted for 40 hours. The benzene: methanol solvent extracts from 4-9% of the organic carbon content of the shale.

The soxhlet extracts were further separated by column chromatography into three fractions - aliphatic, aromatic, and asphaltene. The samples extracted, the percent of total shale extracted and the percent of each fraction from the chromatography separation are given in Table 10. The 04IL sample is from the Henderson County, Illinois core, the 01KY samples are from the Christian County, Kentucky core and the 06IL samples are from the Tazewell County, Illinois core. Three chemical samples 06IL18C1 through 06IL20C1 were combined to give a larger amount of shale from which a reasonable yield of extract could be obtained. The two samples 01KY01L1 and 01KY05L1 were pulverized and combined to give a total of two kilograms of shale for total chemical analysis. The 06IL10C1 sample did not yield a large enough quantity of extract for further analysis.

Elemental analyses were made on the total extracts and the chromatographic fractions. The hydrogen to carbon ratios were calculated from the analytical results. There does not appear to be any significant anomalies in the results. The elemental analyses and H/C ratios are given in Table 11.

The aliphatic fraction from samples 04IL14C1, 01KY07C1 and the composite 06IL18C1 through 06IL20C1 were further separated on molecular sieve into n-paraffins and branched chain paraffins. The n-paraffin fraction was then analyzed by gas chromatography. A typical gas chromatogram is shown in Figure 9. The percent of n-paraffins in the aliphatic fraction, the dominant components, and the odd to even number carbon ratio are given in Table 12. The predominance of odd over even carbon number n-paraffins has generally been found to be true for paraffins derived from sediments. The distribution of the n-paraffins in the three samples is shown in Figure 10.

Isotopic Analysis of Off-Gases

No additional cores have been available containing sufficient methane for isotopic analyses.

Laboratory Study of Chemical and Isotopic Fractionation

Because our preliminary data indicated that significant changes in the chemical and isotopic composition of natural gas can occur during degassing of shales, i.e., during gas flow through the micropores of the shale, further research is being conducted in the laboratory on 3/4" cores pressurized with natural gas. The cores being used in this phase of the study were evacuated in a vacuum oven for approximately 2 months to remove all residual gases. The cores were then sealed into high pressure vessels and evacuated for an additional 3 weeks.

Four pressure vessels contain one shale core each and a fifth contains a brass plug of equivalent size to serve as a blank. The vessels were pressurized to 610 p.s.i.g. with natural gas of known composition, and are being kept submerged in water so that any leakage can be detected. After approximately 20 days, the pressure in the vessels containing the cores dropped on the average about 80 P.S.I. indicating uptake of gas by the shale. During the following 25 days the pressures in three of these vessels dropped at a relatively constant rate of 0.870 P.S.I. per day. The pressure in the vessel containing the blank is holding constant; however, one of the vessels containing a shale core is losing pressure at a rate of about 3 P.S.I. per day indicating a leak. The leak has now been traced to the valve, which is transmitting gas back into the manifold to which the vessels are attached.

Once equilibrium of the gas with the shale is attained, the vessels will be systematically depressurized as a function of time and the gas will be sampled and analyzed to determine whether any chemical or isotopic fractionation has occured.

ADSORPTION/DESORPTION STUDIES OF GASES THROUGH SHALES

Introduction

With nitrogen and carbon dioxide, determine internal surface area on shale core samples; on selected samples, use methane as the adsorbate (sorbate) at pressures within the range of 1 to 80 atmospheres. Comparison of these properties in gas-producing and non-gas-producing shales will be made to determine the relationship of shale physical properties to gas recovery.

Progress

No new core samples were received during this quarter for internal surface area measurements. These measurements have been completed on all the core samples received to date from the Illinois Basin. However, methane adsorption (sorption) isotherms at high pressures are still being produced and studied. Gathering the methane high-pressure data is a necessarily slow process, sometimes taking as much as a week per sample. New isotherms for three samples from Edgar County, Illinois (05IL01L1, 05IL01L2, and 05IL01L3)and the adsorption/sorption isotherms for a sample from Wise County, Virginia, which was received from J. Barry Maynard of the University of Cincinnati, are shown in Figures 11, 12, 13, and 14 respectively.

Earlier we reported that, with the exception of samples from Wise County, Va., samples from the Appalachian Basin that we had studied behaved similarly to those from the southern portion of the Illinois Basin. That is, internal surface area measurements from nitrogen adsorption were appreciably less than those from carbon dioxide adsorption, indicating that average pore sizes were smaller with greater burial depth. The Wise County, Va. samples, however, were somewhat unique in that nitrogen surface area values were about the same as those from CO_2 adsorption. The Wise County, Va. samples came from depths greater than 4000 feet. The methane uptake (total sorption curve shown) does not continue to increase at nearly the same rate as total sorption curves for samples from Christian County, Ky. shown in earlier reports, where some increased sorption is thought to occur in the organic carbon portion of the clay matrix. This increased rate of total sorption is seen to some extent in the 05IL01 samples shown here from Edgar County, Ill. Thus, there is added evidence here that the organic carbon portion of the Wise County, Va. samples has been altered. With our earlier studies of internal surface area, and the higher vitrinite reflectance values, it would appear that the temperature in the geologic past for the Wise Co., Va. samples was much higher than that acquired simply by increased burial depth. The increase was likely due to the catastrophic shearing of fault planes in that vicinity. Reiterating our earlier report, if gas has been trapped in the shale from Wise Co., Va., its release will be much more rapid than from other comparable organic carbon-containing shales that we have studied to date.

Two papers were presented on our studies during this quarter. One by R. R. Frost and J Thomas, Jr. at the 2nd Annual Eastern Gas Shales Symposium held in Morgantown, W. Va., Oct. 16-18. The second by J. Thomas, Jr. was presented at the 27 Annual Clay Minerals Conference held in Bloomington, Indiana, Oct. 8-12, 1978.

Table 2. Relative composition of the pyrolytic organic fraction for shale S00060

°C Temp \ %	$<C_8$	C_9-C_{12}	$C_{13}-C_{16}$	$C_{17}-C_{20}$	$C_{21}-C_{24}$	$C_{25}<$
250	51.79	42.00	6.22	--	--	--
350	45.98	32.13	18.85	2.89	0.15	--
550	51.71	24.65	15.16	6.79	1.37	--
750	72.98	14.13	8.10	3.34	1.26	0.16

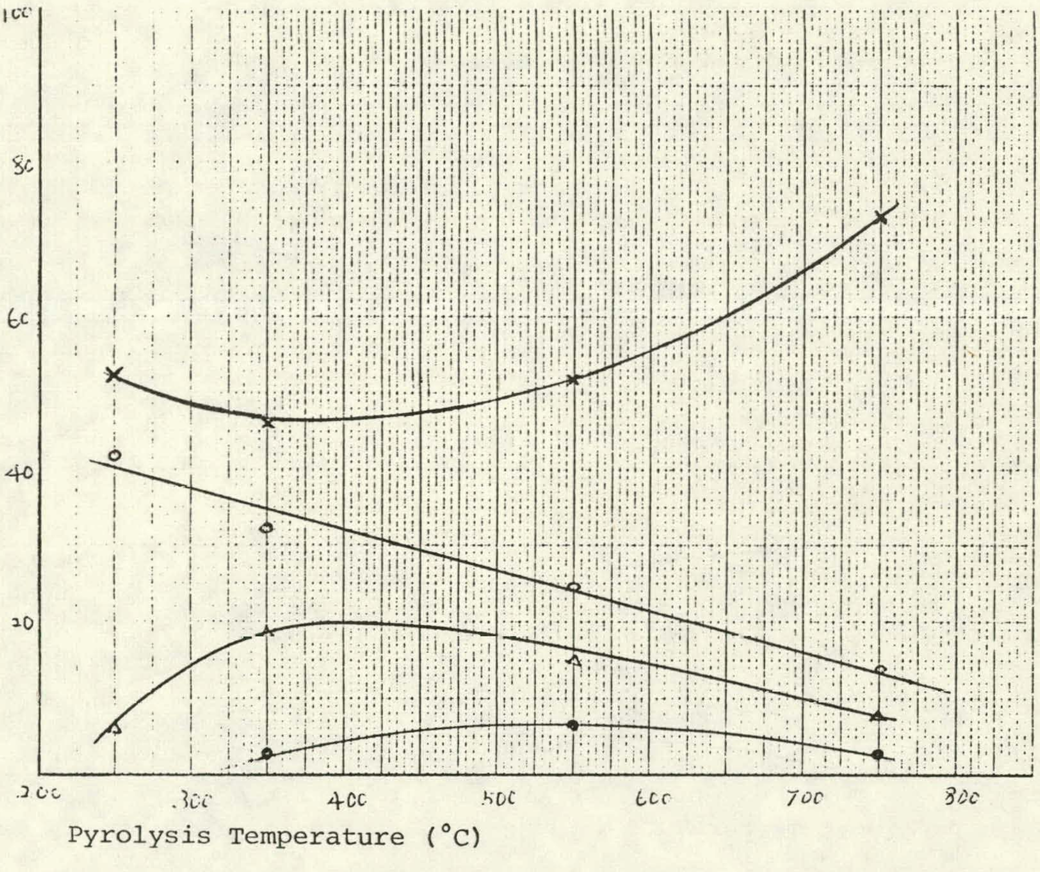


Fig. 1 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale S00060

x = fraction $<C_8$
o = fraction C_9-C_{12}
Δ = fraction $C_{13}-C_{16}$
• = fraction $C_{17}-C_{20}$

Table 3. Relative composition of the pyrolytic organic fraction for shale S00095

°C Temp \ %	<C_8	C_9-C_{12}	C_{13}-C_{16}	C_{17}-C_{20}	C_{21}-C_{24}	C_{25}<
250	67.65	28.91	3.44	--	--	--
350	60.61	28.90	7.97	2.52	--	--
550	62.39	19.14	9.46	4.41	3.02	1.55
750	72.60	15.91	7.44	2.12	1.94	trace

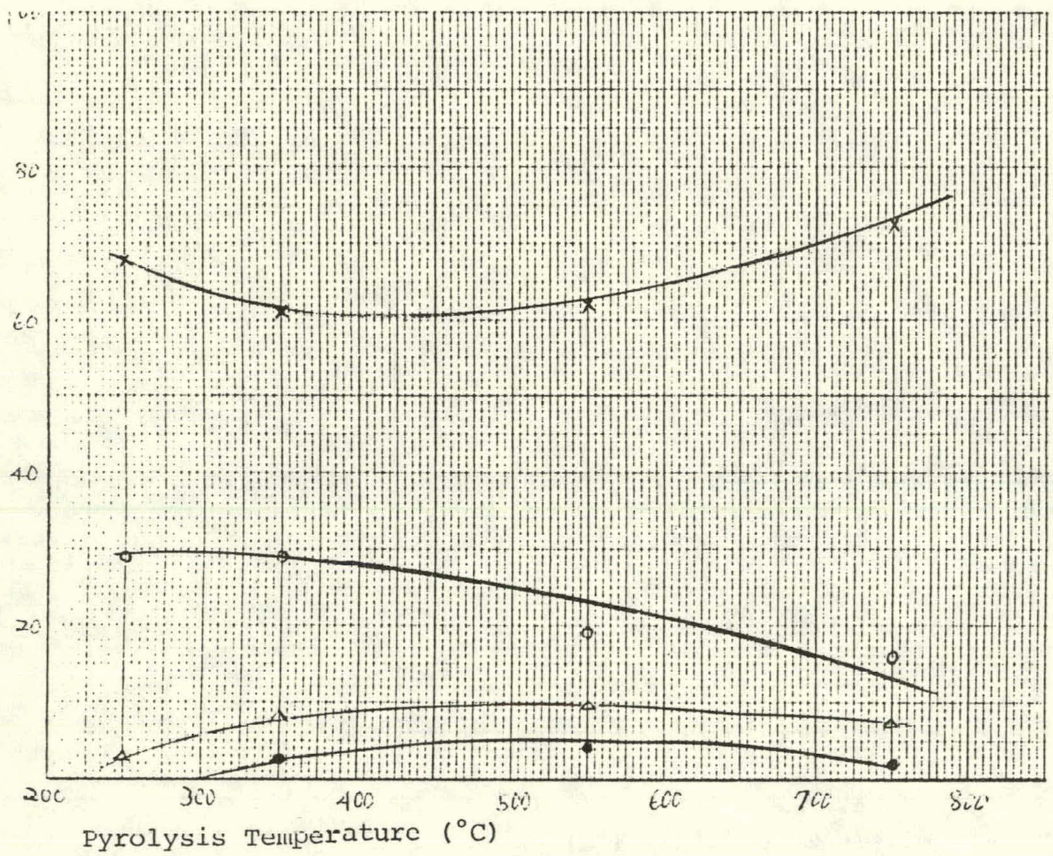
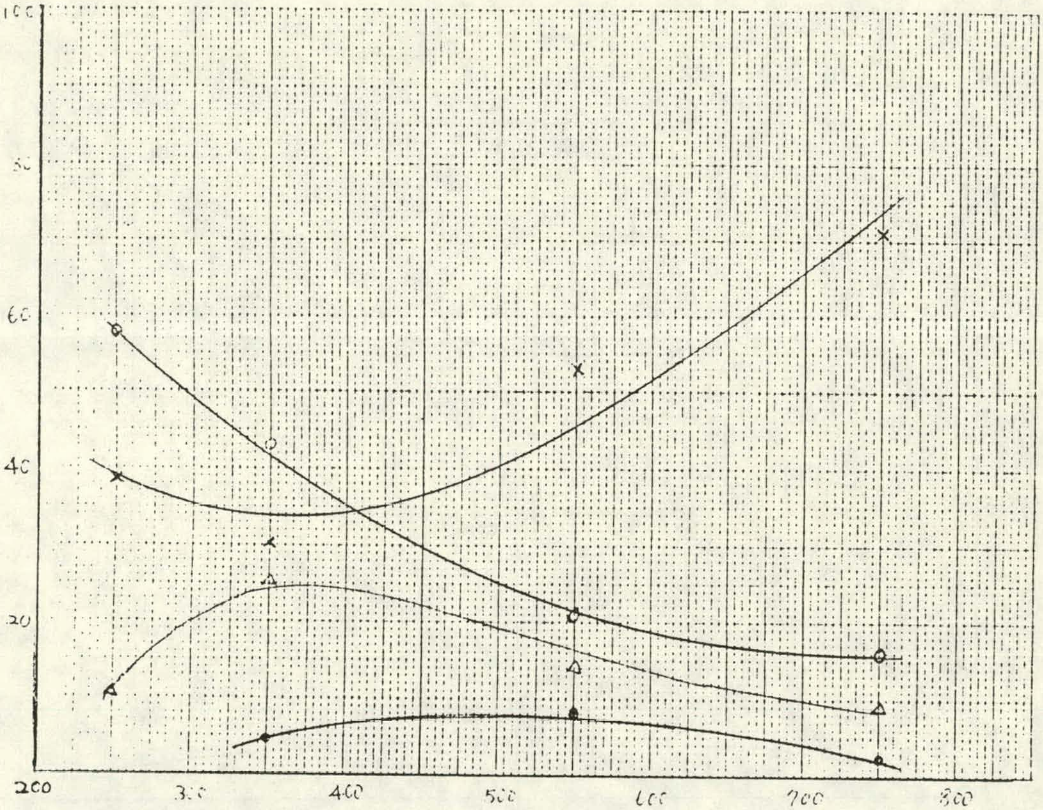


Fig. 2 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale S00095

x = fraction <C_8
o = fraction C_9-C_{12}
Δ = fraction C_{13}-C_{16}
• = fraction C_{17}-C_{20}

Table 4. Relative composition of the pyrolytic organic fraction for 02IL04Cl

°C Temp	%	$<C_8$	C_9-C_{12}	C_{13}-C_{16}	C_{17}-C_{20}	C_{21}-C_{24}	$C_{25}<$
250		37.53	57.03	5.44	--	--	
350		25.29	42.82	25.35	4.37	1.28	
550		52.94	21.09	14.12	7.91	2.46	
750		70.97	15.95	9.14	2.63	0.97	



Pyrolysis Temperature (°C)

Fig. 3 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale 02IL04Cl

x = fraction $<C_8$
o = fraction C_9-C_{12}
Δ = fraction C_{13}-C_{16}
• = fraction C_{17}-C_{20}

Table 5. Relative composition of the pyrolytic organic fraction for shale 01KY07Cl

°C Temp \ %	<C_8	C_9-C_{12}	C_{13}-C_{16}	C_{17}-C_{20}	C_{21}-C_{24}	C_{25}<
250	68.86	28.65	2.50	--	--	--
350	60.67	32.09	6.98	--	--	--
550	62.00	30.61	6.24	1.15		
750	81.94	10.88	4.76	1.37	1.07	--

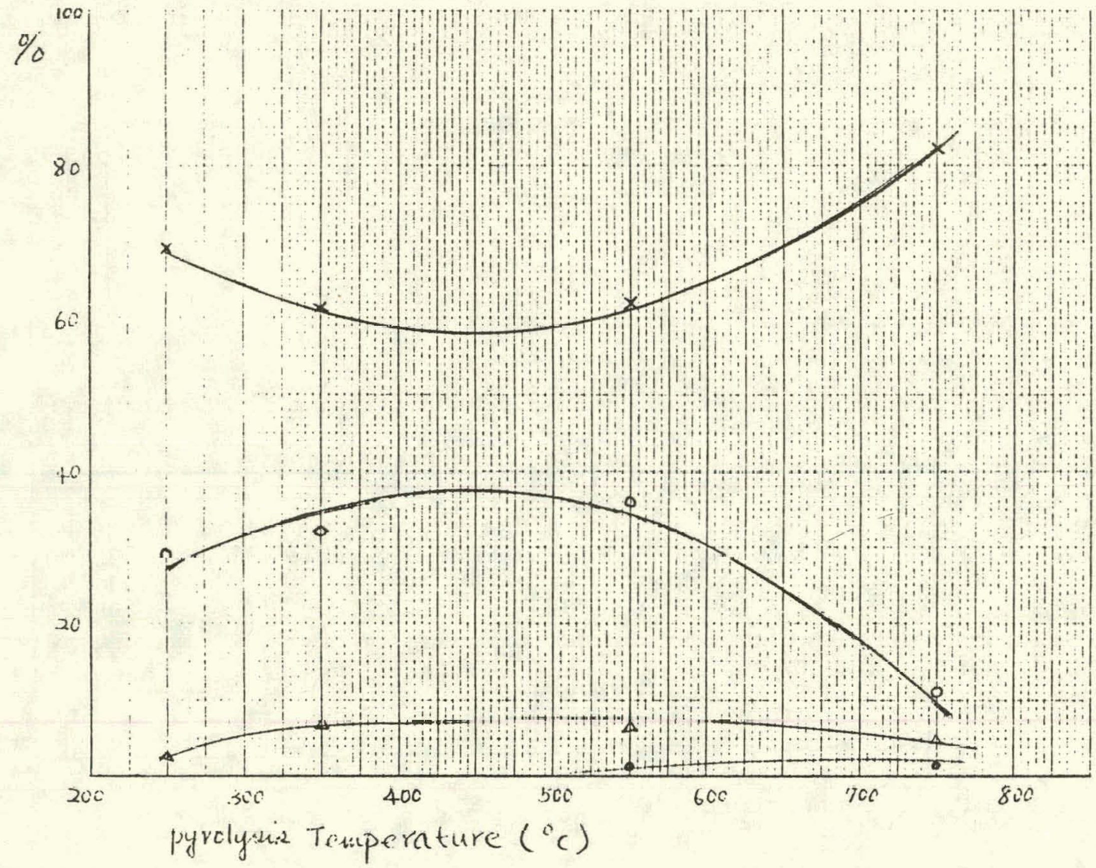
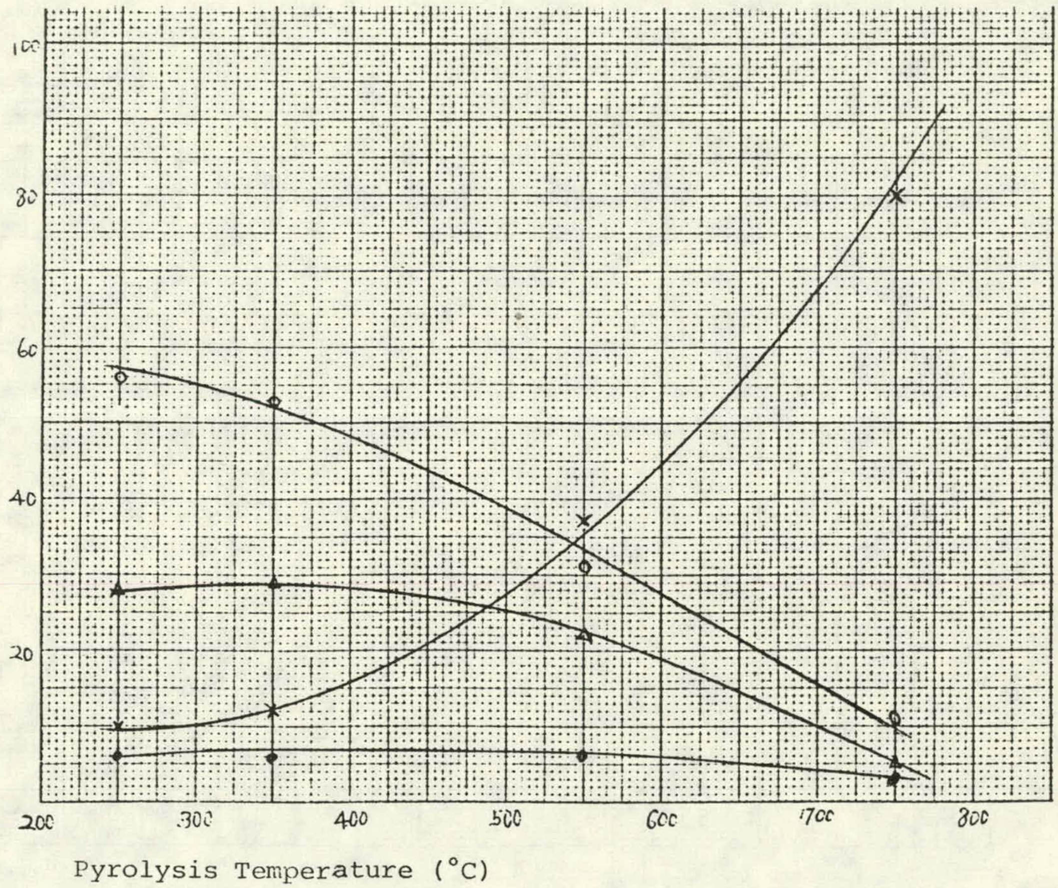


Fig. 4 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale 01KY07Cl

x = fraction <C_8
o = fraction C_9-C_{12}
Δ = fraction C_{13}-C_{16}
• = fraction C_{17}-C_{20}

Table 6. Relative composition of the pyrolytic organic fraction for shale 01KY12C1 (S00012)

Temp (°C) \ %	<C_8	C_9-C_{12}	C_{13}-C_{16}	C_{17}-C_{20}	C_{21}-C_{24}	C_{25}<
250	9.69	55.91	27.69	6.71	-	-
350	12.17	52.76	27.89	5.91	2.24	-
550	37.20	30.63	21.76	6.68	3.24	0.50
750	79.97	11.26	5.03	2.77	0.94	0.03



Pyrolysis Temperature (°C)

Fig. 5 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale 01KY12C1 (S00012)

x = fraction <C_8
o = fraction C_9-C_{12}
Δ = fraction C_{13}-C_{16}
• = fraction C_{17}-C_{20}

Table 7. Relative composition of the pyrolytic fraction for shale 06IL19C1 (S00088)

Temp (°C) \ %	$<C_8$	C_9-C_{12}	C_{13}-C_{16}	C_{17}-C_{20}	C_{21}-C_{24}	$C_{25}<$
250	44.20	46.91	8.63	0.27	-	-
350	33.46	53.23	12.06	1.20	0.05	-
550	38.77	32.86	19.78	7.62	0.94	0.05
750	54.63	18.81	13.51	8.96	3.44	0.69

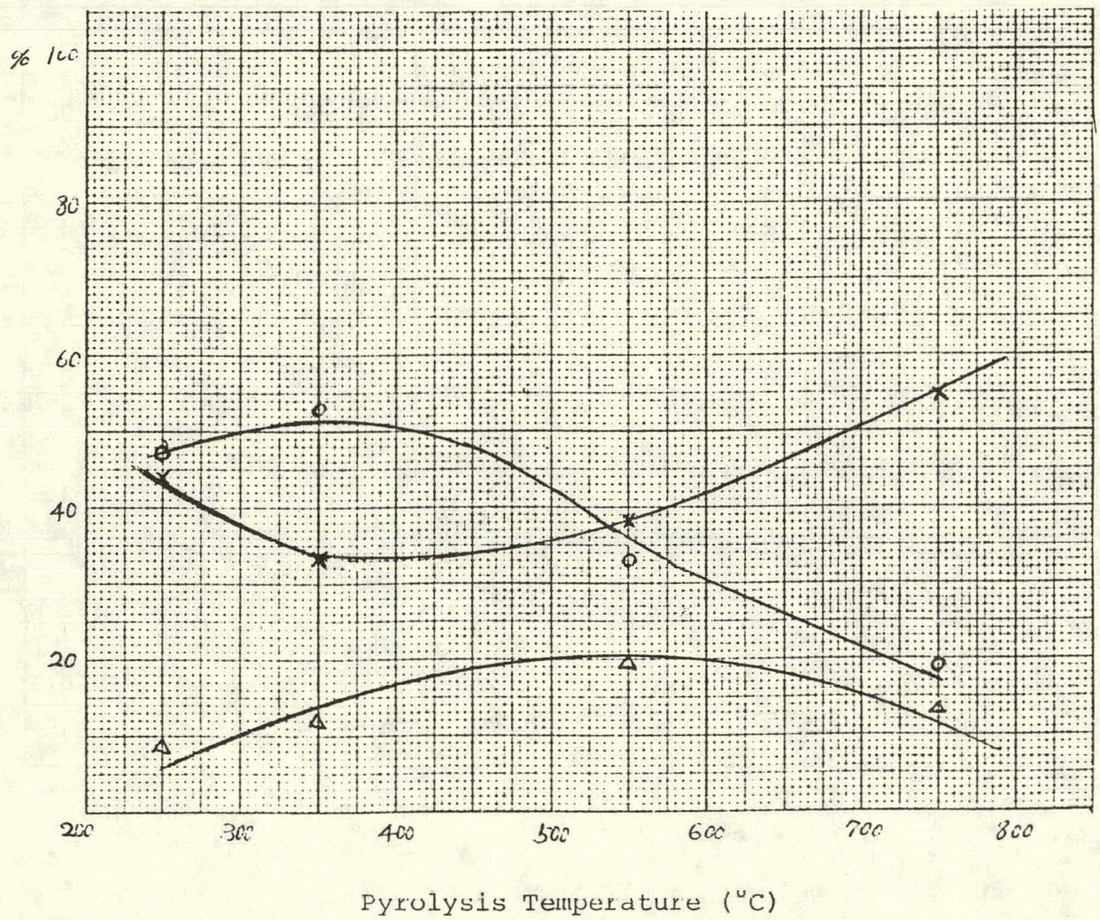
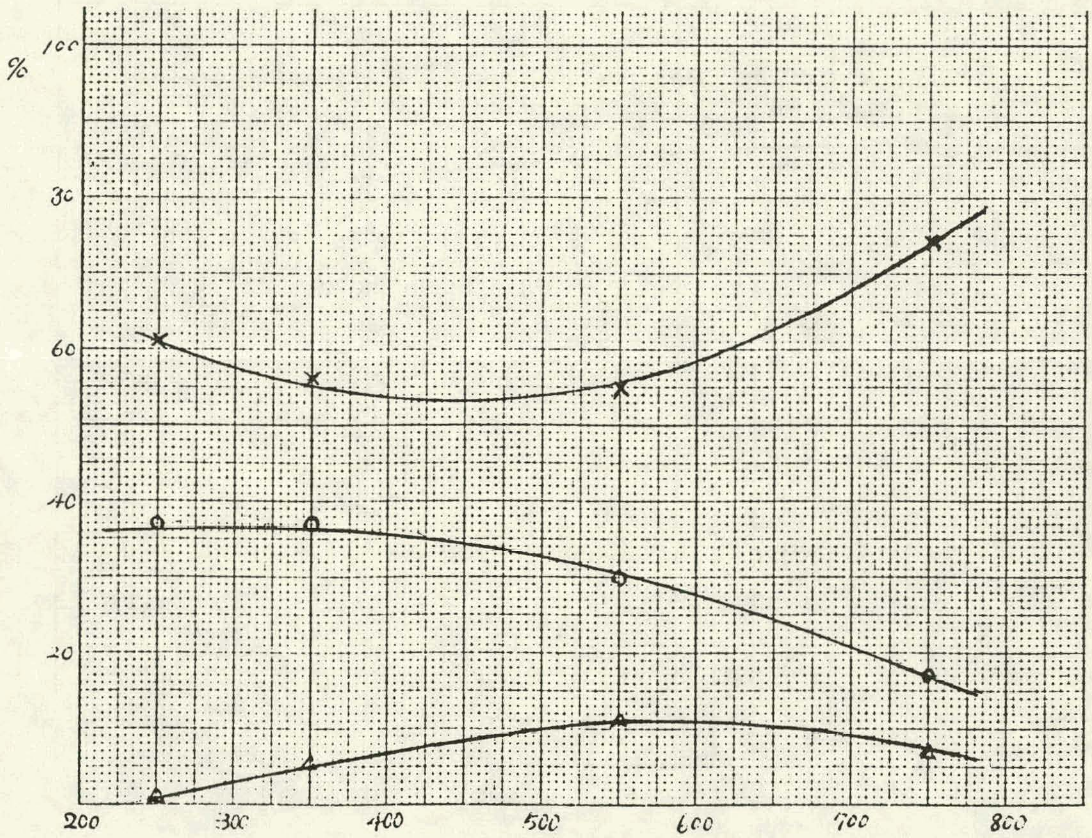


Fig. 6 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale 06IL19C1 (S00088)

x = fraction $<C_8$
o = fraction C_9-C_{12}
Δ = fraction C_{13}-C_{16}

Table 8. Relative composition of the pyrolytic organic fraction for shale 06IL20Cl (S00089)

Temp (°C) \ %	<C_8	C_9-C_{12}	C_{13}-C_{16}	C_{17}-C_{20}	C_{21}-C_{24}	C_{25}<
250	60.89	37.46	1.65	-	-	-
350	56.62	37.30	5.54	0.55	-	-
550	55.11	24.95	11.55	6.98	1.00	-
750	74.58	17.22	7.35	0.75	0.10	-



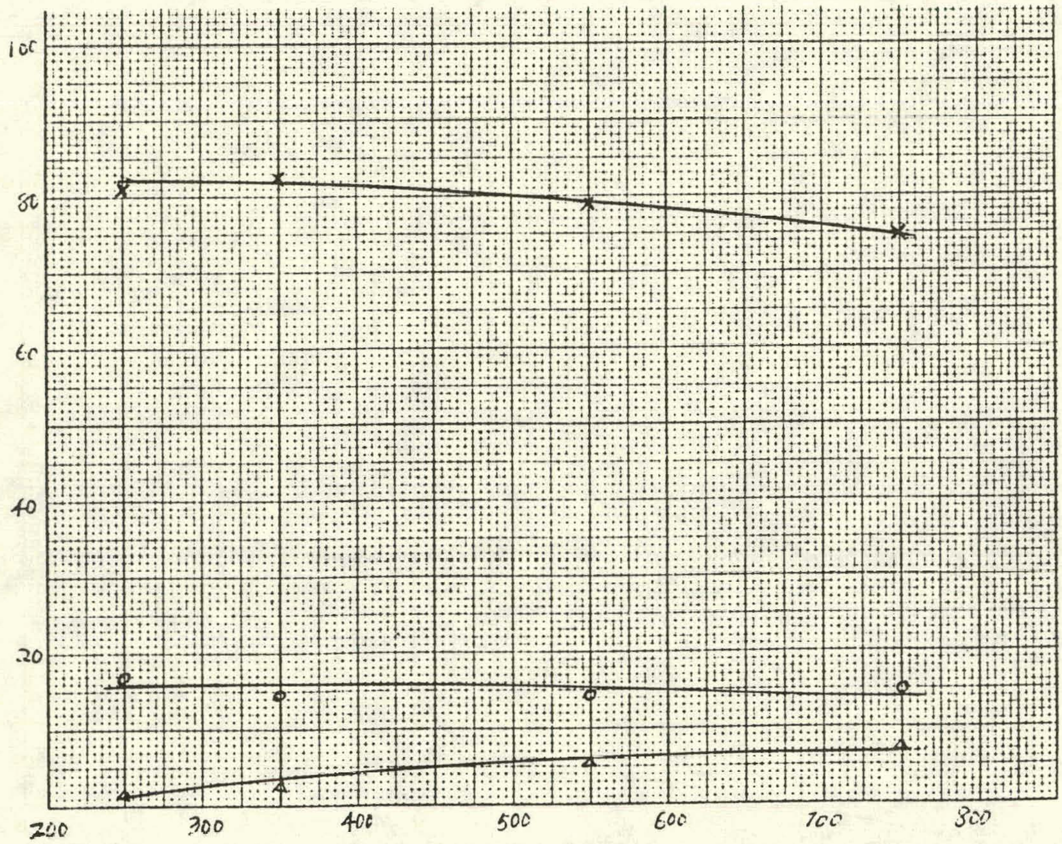
Pyrolysis Temperature (°C)

Fig. 7 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale 06IL20Cl (S00089)

x = fraction <C_8
o = fraction C_9-C_{12}
Δ = fraction C_{13}-C_{16}

Table 9. Relative composition of the pyrolytic organic fraction for shale composite of 01KY01L1 and 01KY05L1

Temp (°C) \ %	$<C_8$	C_9-C_{12}	$C_{13}-C_{16}$	$C_{17}-C_{20}$	$C_{21}-C_{24}$	$C_{25}<$
250	81.34	17.28	1.38	-	-	-
350	82.44	14.46	2.64	0.46	-	-
550	78.91	14.35	5.69	0.86	0.21	-
750	75.24	15.02	7.48	1.98	0.76	0.66



Pyrolysis Temperature (°C)

Fig. 8 The percentage of the pyrolytic organic fraction as a function of the pyrolysis temperature for shale composite of 01KY01L1 and 01KY05L1

x = fraction $<C_8$
o = fraction C_9-C_{12}
Δ = fraction $C_{13}-C_{16}$

Table 10. Soxhlet Extraction, Column Chromatography of Eastern Black Shale

Sample name	Organic Carbon(%)	Benzene-MeOH Extract (%)	Chromatography fraction (%) recovery	aliphatic	aromatic	asphaltene
04IL14C1	3.1	0.27	94.6	18.9	16.2	59.5
01KY07C1	12.3	0.50	97.3	21.9	38.4	37.0
06IL18C1 06IL19C1 } a 06IL20C1	7.0[b]	0.54	94.3	29.8	24.8	39.7
06IL10C1	0.7	0.03	--	--	--	--
06IL25C1	3.3	0.28	90.0	30.0	26.7	33.3
01KY01L1 01KY05L1 } a	9.0[b]	0.49	90.9	24.2	24.8	41.9

a) composite sample
b) mean for composite

Table 11. The Elemental Analysis and Hydrogen/Carbon Ratio of Extract and Fraction from Extract

Sample name	Element	Extract (Benzene-Methanol)	Chromatography fraction Aliphatic	Aromatic	Asphaltene
04IL14C1	C	82.81	86.54	87.88	73.98
	H	9.35	12.66	9.81	7.24
	N	1.65	≤0.16	≤0.21	2.24
	S	-	-	-	1.16
	H/C	1.34	1.74	1.33	1.16
01KY07C1	C	84.00	86.40	87.51	81.19
	H	9.10	13.09	9.11	7.95
	N	1.81	0.00	0.34	3.19
	S	1.62	-	-	1.34
	H/C	1.29	1.80	1.24	1.16
06IL18C1 06IL19C1 * 06IL20C1	C H N	82.38 9.61 1.75	87.19 12.16 0.00	85.96 9.43 1.02	79.52 8.15 3.01
	S	1.16	-	-	1.47
	H/C	1.39	1.66	1.31	1.22
06IL25C1	C	82.57	86.43	86.69	80.95
	H	10.51	13.22	10.00	8.22
	N	0.92	0.00	0.00	2.02
	S	1.42	-	-	1.76
	H/C	1.51	1.82	1.37	1.21
01KY01L1 * 01KY05L1	C H	85.31 9.81	87.00 13.09	87.54 8.99	80.52 8.20
	N	1.76	0.00	0.78	3.56
	S	1.01	-	-	1.02
	H/C	1.37	1.79	1.22	1.21

* Composite

Table 12. GC Analysis of Aliphatic Fraction from Eastern Black Shale Extract

Sample name	n-paraffin/ Aliphatic fraction	Dominant components in n-paraffin	odd number carbon/ even number carbon
04IL14C1	36.44%	C_{17}, C_{18}, C_{15}	1.45
01KY07C1	64.32%	C_{14}, C_{15}, C_{17}	1.05
06IL18C1 06IL19C1 * 06IL20C1	68.14%	C_{15}, C_{17}, C_{14}	1.41

* composite

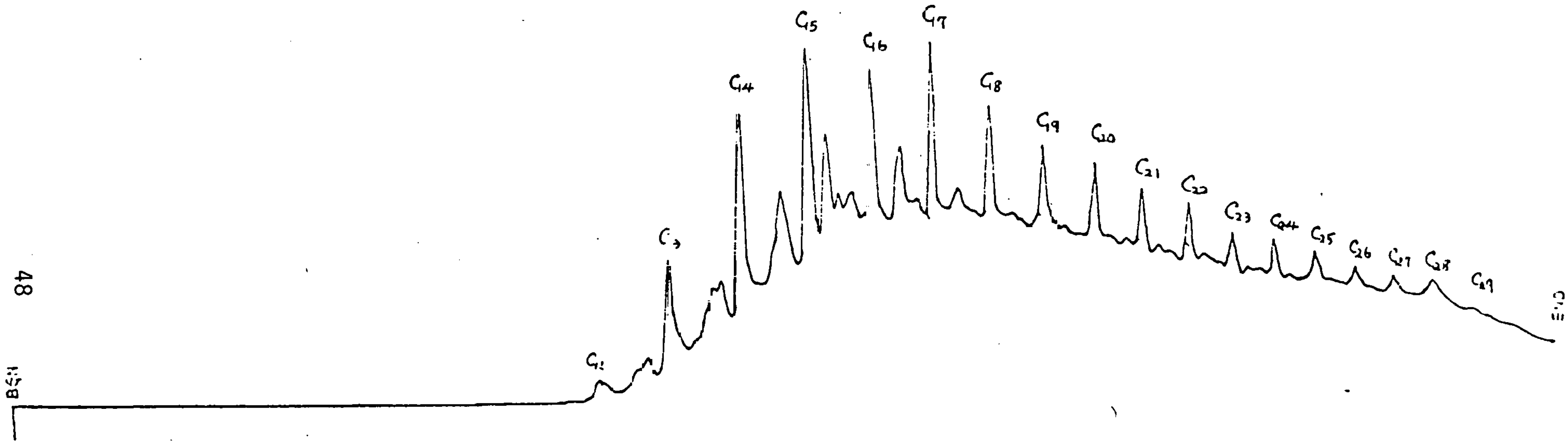


Fig. 9 : G.C. trace of the normal alkane distribution in shale 01KY07C1 extract.

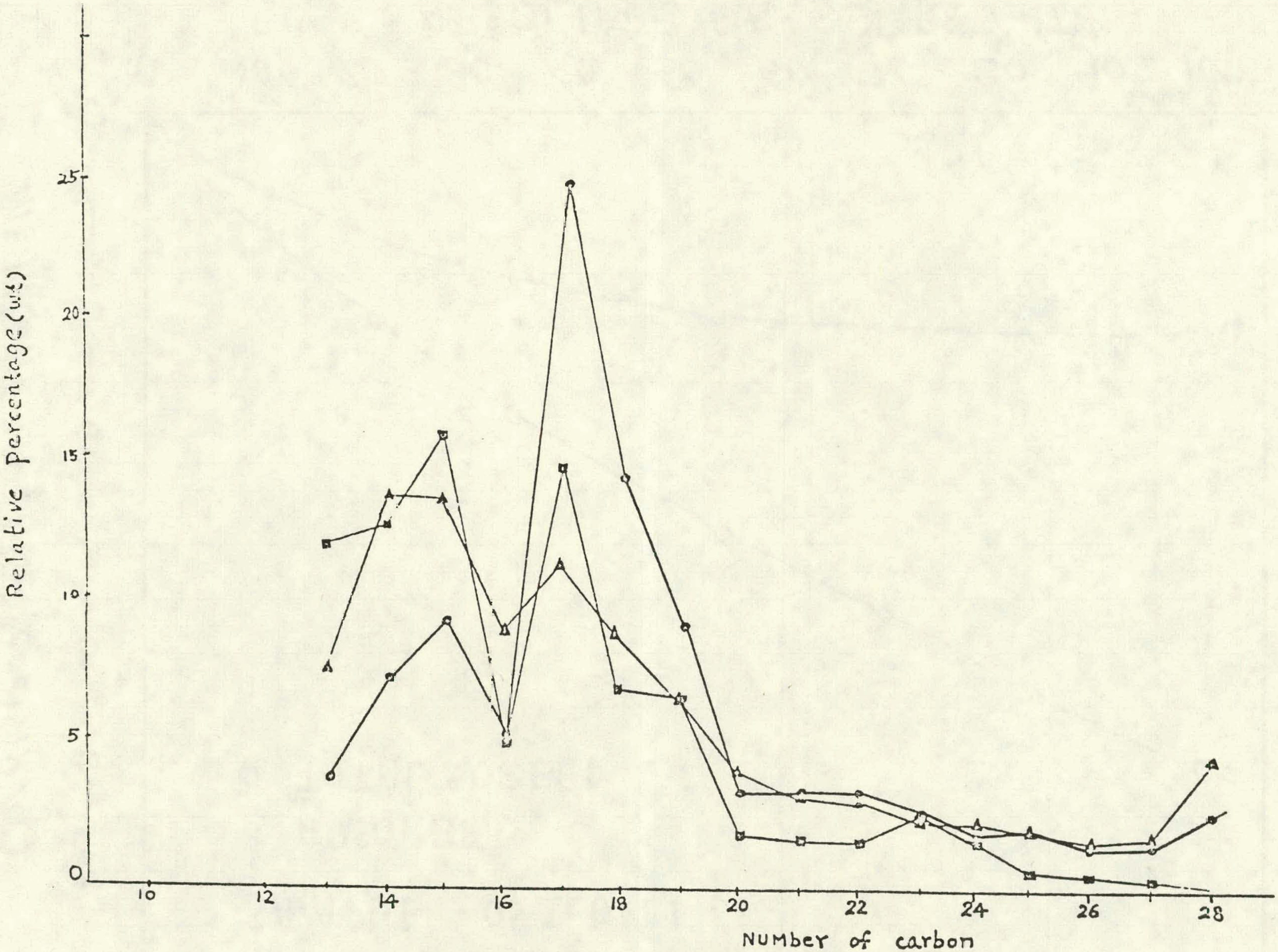
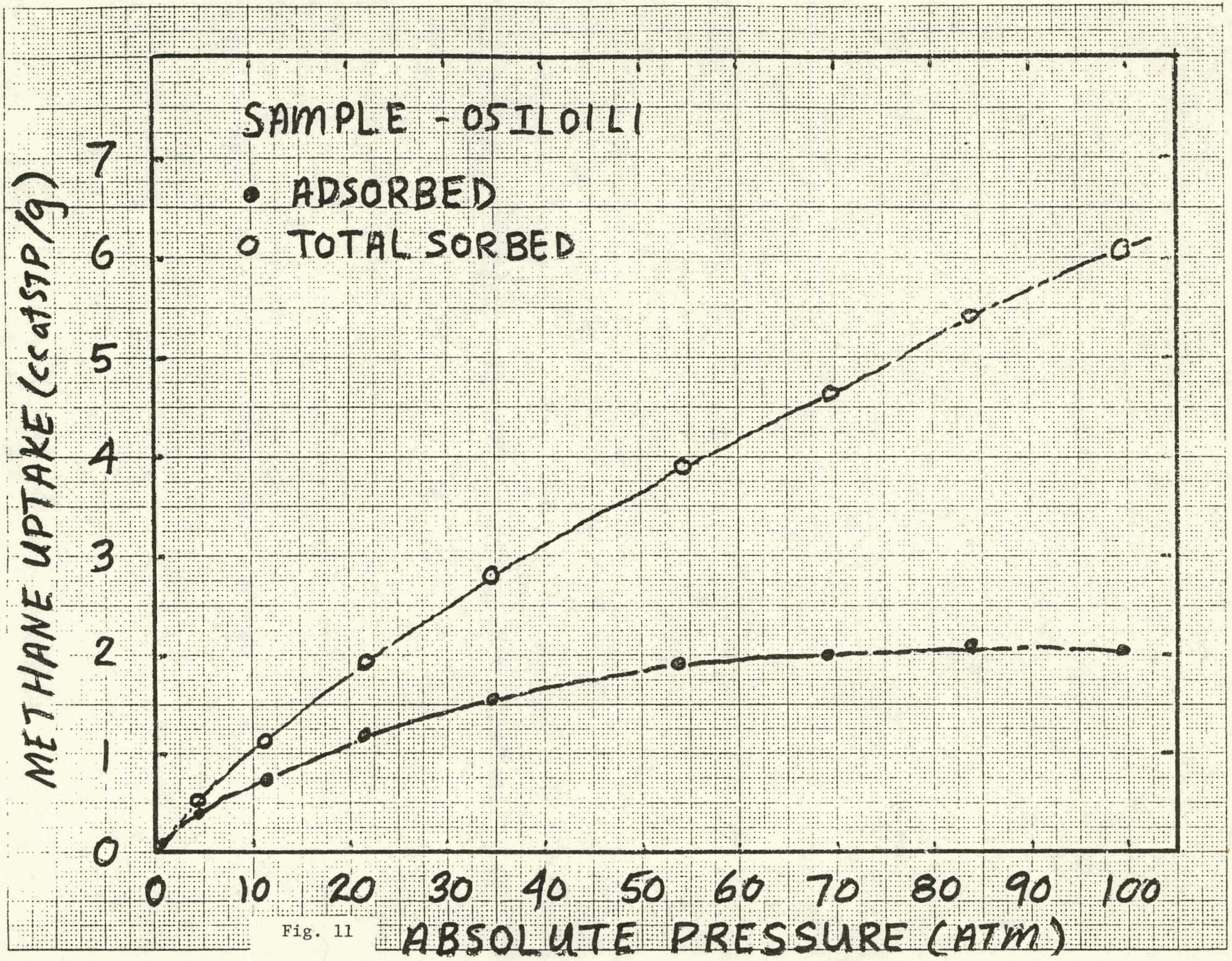


Fig.10 : The distribution of n-paraffin in 04IL14C1 (●), 01KY07C1 (▲) and 06IL18~20C1 (■)
Aliphatic extract.



SAMPLE - OSILOILI
• ADSORBED
o TOTAL SORBED
METHANE UPTAKE (cc at STP/g)
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100
ABSOLUTE PRESSURE (ATM)

Fig. 11

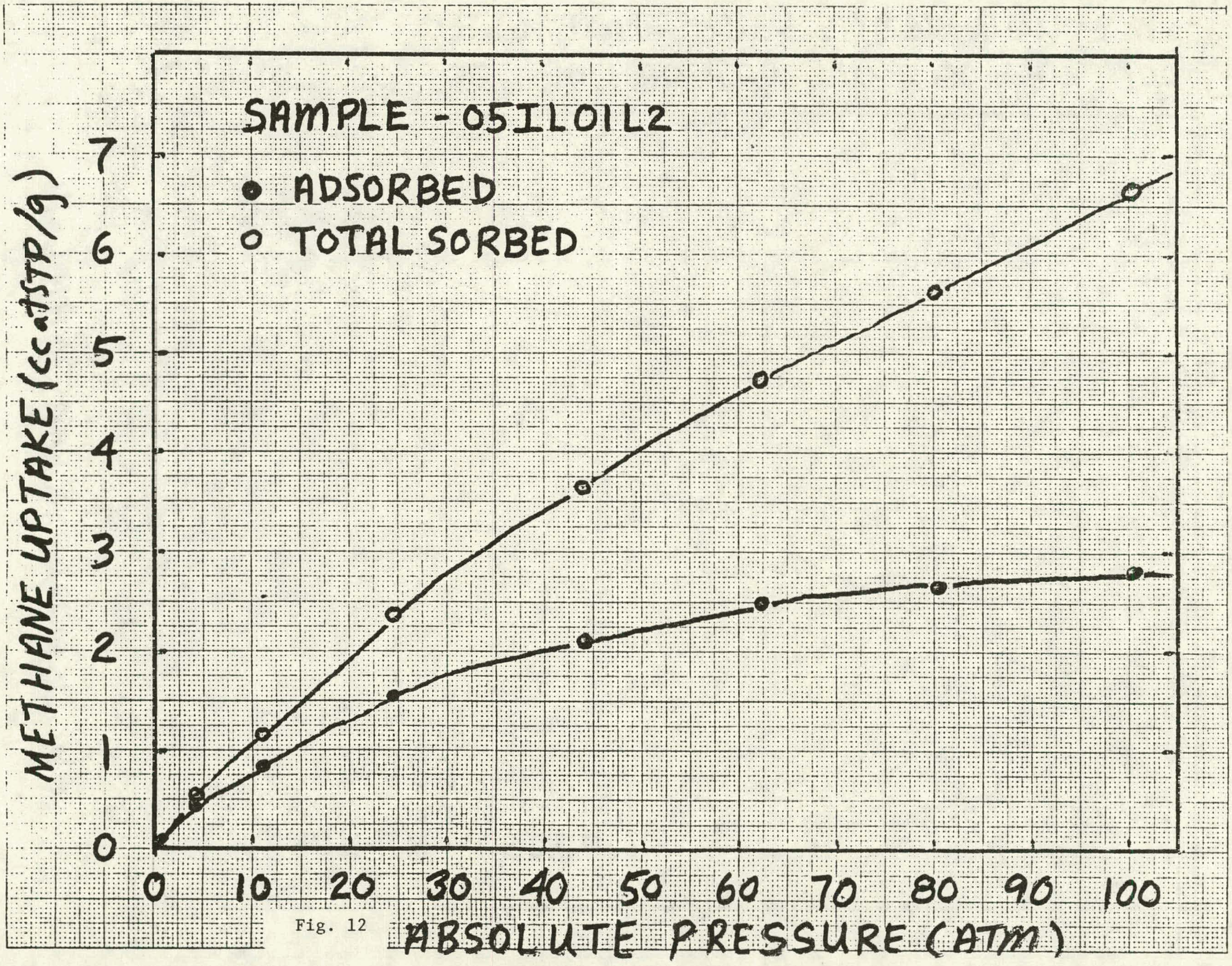

SAMPLE - 05IL01L2
ADSORBED
TOTAL SORBED
METHANE UPTAKE (cc at STP/g)
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100
ABSOLUTE PRESSURE (ATM)

Fig. 12

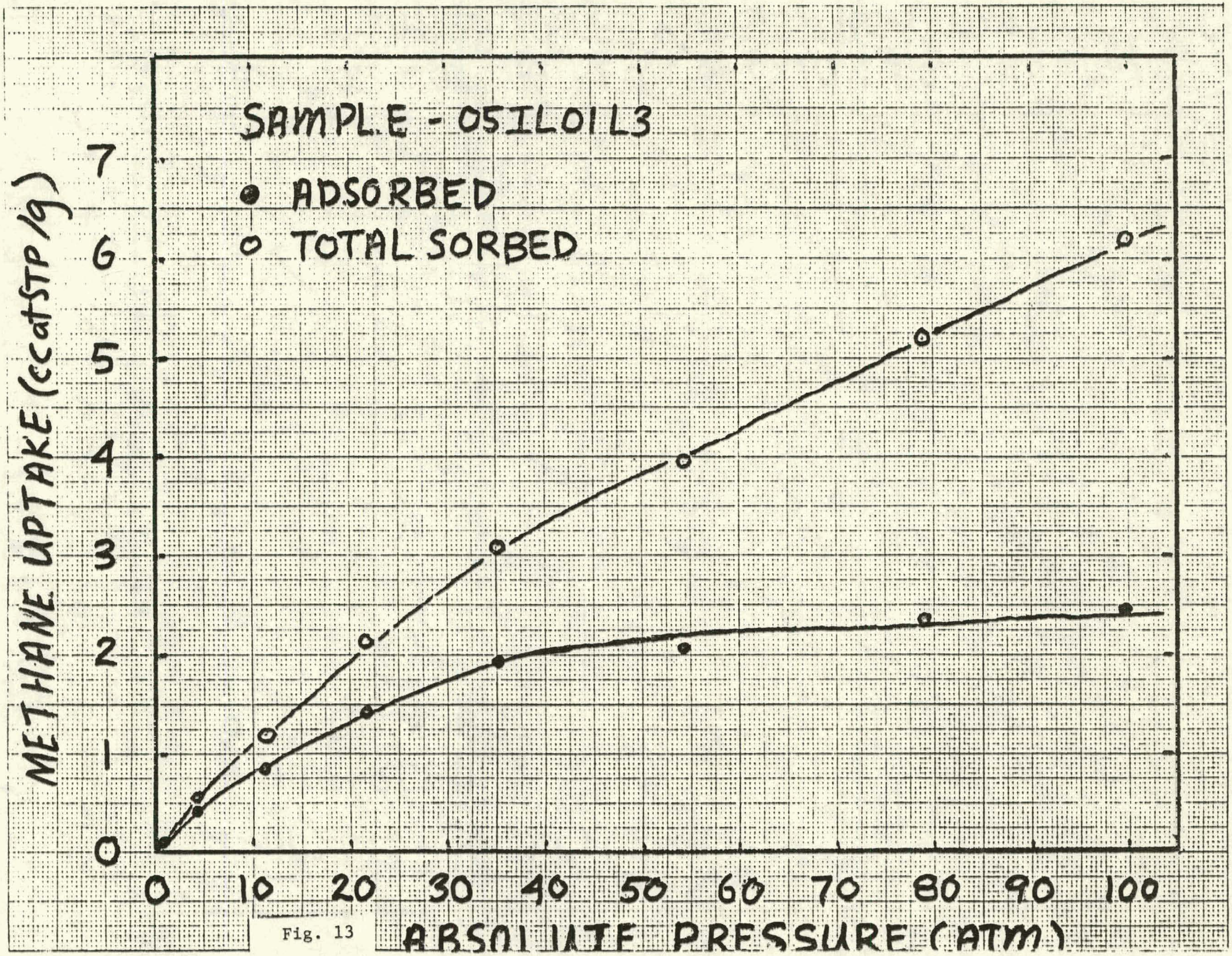

SAMPLE - 05IL01L3
ADSORBED
TOTAL SORBED
METHANE UPTAKE (cc at STP/g)
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100
ABSOLUTE PRESSURE (ATM)

Fig. 13

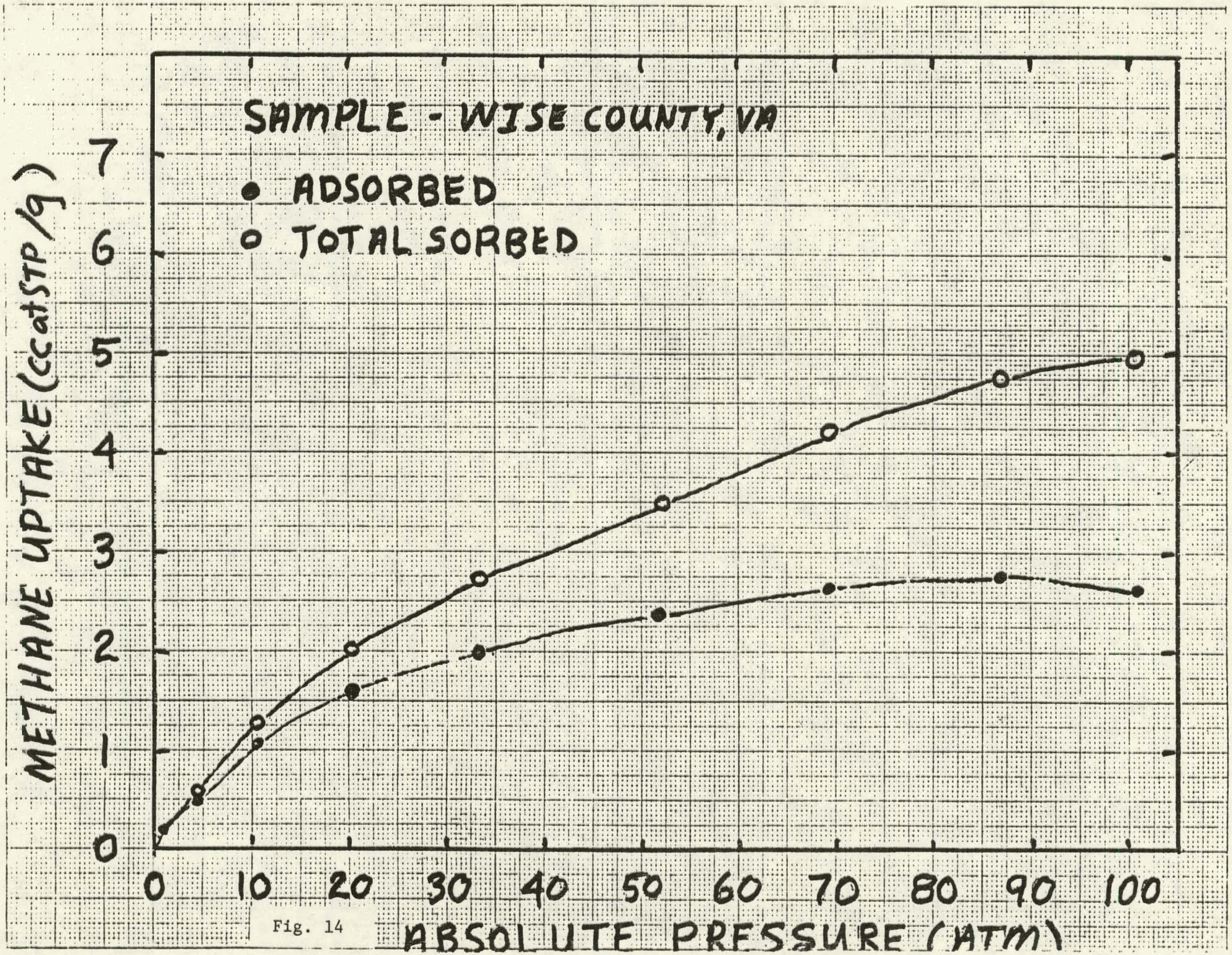


Fig. 14

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